JOURNAL OF ANIMAL SCIENCE

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SELECTION FOR AN INCREASE IN GROWTH RATE AND MARKET SCORE IN TWO INBRED LINES OF SWINE[1]

N. C. FINE[2] and L. M. WINTERS[3]

Minnesota Agricultural Experiment Station

AN earlier paper (Fine and Winters, 1952) reported a study of selection for fertility in two inbred lines of swine. The present paper reports on the results of selection in the same inbred lines (the Minnesota No. 1 and No. 2) for traits which are expressed in both sexes. The traits studied were score as to market desirability and rate of growth. Laben and Whatley (1947) studied an inbred line of Durocs in which selected individuals averaged 22 pounds heavier than their generation at 180 days of age, yet the line average 180-day weight declined from 187 pounds to 153 pounds. Generation average conformation scores remained about the same, although selected animals averaged in conformation score 2.3 points above their generation average. Likewise, Kottman, Lush and Hazel (1948) calculated that the levels of performance, including weight at 154 days, in some Poland-China inbred lines were generally below what should be expected taking into account the positive selection differentials achieved, the heritability estimates, and the negative effects of inbreeding. Dickerson and Grimes (1947) were successful in developing from a foundation of Durocs two strains, one strain being inferior in efficiency of feed utilization and the other superior in efficiency of feed utilization. Efficiency was measured by the amount of feed required per 100 pounds of gain by pigs fed individually. Krider *et al.* (1946) described an experiment in selecting for slow and rapid growth in Hampshires. They were apparently successful in producing two rather distinct lines, if one may judge by the recent report of Baird, Nalbandov and Norton (1952). All of the workers just mentioned used one of the purebred swine breeds as experimental material. Laben and Whatley (1947) and Kottman, Lush and Hazel (1948) reported considerable inbreeding, while Dickerson and Grimes (1947) and Krider *et al.*

[1] Paper No. 2916, Scientific Journal Series of the Minnesota Agricultural Experiment Station in cooperation with the Regional Swine Breeding Laboratory, Ames, Iowa, Bureau of Animal Industry, U.S.D.A. This paper is condensed from a portion of a thesis submitted to the Graduate Faculty of the University of Minnesota in partial fulfillment of the requirements for the degree of doctor of philosophy.

[2] Formerly graduate student at the University of Minntsota, now Assistant Dean of Agriculture and Professor of Animal Husbandry at Texas Technological College.

[3] Professor of Animal Husbandry at the University of Minnesota.

(1946) made some effort to avoid inbreeding. The experimental material for the present study consisted of two inbred lines of swine which rested on foundations which were initially cross bred.

Materials and Methods

The Minnesota No. 1 and Minnesota No. 2 inbred lines providing the data for this study were developed from crossbred foundations which should have been highly heterozygous to begin with. The Minnesota No. 1 was developed from a Danish Landrace-Tamworth crossbred foundation (Winters, Comstock and Dailey, 1943). The Minnesota No. 2 descended from a foundation resulting from matings between two Poland-China inbred lines and an outbred Yorkshire boar (Winters *et al.*, 1948).

The method of analysis was basically that suggested by Comstock and Winters (1944) who predicted the rate of change per generation in phenotypic merit by the formula,

$$y=bI+sH$$

where y is the expected change per generation in the trait

b, the average change in the trait per unit of inbreeding, I, when $sH=0$

I, the increase in inbreeding per generation

s, the selection differential

H, the heritability estimate of the trait

The Comstock and Winters formula was modified to give the theoretical rate of change per year, m, by simply changing I to mean the increase in inbreeding per year and dividing the term sH by G, which is the average interval in years between generations. The formula then becomes

$$m=bI+sH/G$$

Making use of such a formula requires the determination of values for the different symbols. These values may be found in table 2. I, the increase in inbreeding (F_x) per year, was 3.2 percent and 3.1 percent for the Minnesota No. 1 and No. 2, respectively. Values of G (the average age of the parents when their offspring are born) was 1.62 years and 1.52 years for the Minnesota No. 1 and No. 2 respectively. These terms are common to a study of all three traits. Values for the other symbols, s, b, and H, were either calculated from the data or were taken from the literature.

The preceding method of computing expected change per year could result in an underestimate of m if much attention was given to progeny

performance in the selection of older boars and sows. No attempt was made to measure the extent that selection was based on progeny information, but it is probable that the progeny exercised some influence on the selection of the older animals.

Selection for Score

A score for market desirability was assigned to individuals in tested litters at about the time the individuals were of approximately market weight. In the Minnesota No. 1, for the period 1938 to 1943 inclusive, and in the Minnesota No. 2, for the period 1942 to 1943 inclusive, the scores were assigned on the basis of 54 as a perfect score. In 1944 and following years the score of 9 was the maximum possible score. In order to make the annual selection differentials comparable, it was necessary to reduce the scores of the first years, 1938 to 1943 inclusive, from a basis of 54 to a basis of 9. The breakdown of the score, 54, suggested a possible way of making the reduction. The items on which the score of 54 was based were:

(1) Vigor, health, and thrift	9
(2) Quality	9
(3) Length of body	9
(4) Conformation	9
(5) Animal as a whole	9
(6) Grade	9
Total	54

Each animal scored, male or female, received scores on each of the six items, and the six scores were totaled to give the total score for the animal. Those familiar with the systems of scoring used in the project suggested that item (5), "animal as a whole," should be comparable with the score used in 1944 and following years where the scoring was done with 9 as the maximum possible score. Accordingly, the original data on score as to market desirability furnished, under the heading, "animal as a whole," an estimate of what the score would have been had the animal been scored on the basis of 9 instead of 54.

Values of s (selection differential for score) were computed by sexes and years for each line. They may be found in table 1 along with the herd average scores by years. The values of s in the females were obtained by comparing the score of each female selected with

the herd average of the year in which she was scored. A female was considered to be a selected female after it was seen that she became in the following spring the dam of a test litter and would therefore have offspring available for selection. Test litters were those litters chosen at weaning time and placed on feed in test lots. Practically all replacements were selected from test litters. The female's influence for good or bad, measured by her superiority or inferiority to the herd average of the year in which she was scored, was weighted in proportion to the number of her female offspring available to be selected. In the few cases where the selected animal had not been scored, the score was estimated to be the same as the herd average. The selection differential in males was computed in the same way except the differential in each boar was weighted by the number of daughters of that boar available for selection from test litters. The average values of s in the Minnesota No. 1 and Minnesota No. 2 were 0.70 point and 0.60 point respectively.

Estimates of H of market score have not been calculated from Minnesota data. For an indication as to what heritability of score might be, the study of Stonaker and Lush (1942) indicated that in Poland-China the heritability of conformation score was 20 percent. Although later estimates of heritability of this trait are higher (Whatley and Nelson, 1942; Hetzer, Dickerson and Zeller, 1944), the lower estimate 20 percent was used for both the Minnesota No. 1 and No. 2 because no estimate of the value of b was available. The b would be expected to have a negative value, so that omitting it from the formula would tend to cause m to over-estimate the theoretical progress. For this reason it was thought best to use the lower value of H.

Selection for Growth Rate

Growth rate has been measured by the weight at 154 days. Prior to 1943, the rate of growth was measured by the weight at 180 days. In order to make the selection differentials more nearly comparable for all years, it was necessary to adjust the weight records of the early years of the project (1938–1942) to a 154-day basis. Since the animals were not weighed at 154 days, it was decided to tabulate the weights which were taken at the age closest to 154 days (usually about 140 days) and correct these weights to a 154-day basis by applying a formula which basically is the same one offered by Nordskog (1943). The formula is:

$$94 \times \frac{\text{weight}}{\text{age in days} - 60} = \text{154-day weight}$$

In the Minnesota No. 1, 351 different females and 50 different boars became the sires and dams of the spring farrows of 1939 to 1949, inclusive. Comparable figures for the No. 2 for the spring farrows of 1943 to 1949 inclusive were 29 different boars and 166 different females. Selection differentials for weight at 154 days were computed as already described for score with the exception that the differentials in each sex were determined by measuring from the herd average for that sex in the appropriate year. Males were slightly heavier at 154 days. Values of s for both lines may be found in table 1.

Estimates of H (heritability) of 180-day weights (Baker *et al.*, 1943; Hazel, 1943; Whatley and Nelson, 1942) have ranged from 23 to 30 percent. A somewhat lower heritability estimate, 14 percent, for 180-day weight was obtained from Minnesota data by Comstock *et al.* (1942). A later estimate from Minnesota data (Nordskog, Comstock and Winters, 1944) on the heritability of 168-day weights was 27 percent. Nordskog *et al.* (1944) showed that the relative importance of heredity on aggregate gains after weaning tended to increase with time after weaning. It may be, then, that the heritability of 154-day weight is a little less than 168-day weight, so that 25 percent would be a reasonable heritability estimate to be applied to the Minnesota No. 1 and No. 2 data. Reducing this estimate in proportion to $1-F$, where F is the average inbreeding coefficient for each line, gives average heritability estimates of 19 and 20 percent in the No. 1 and No. 2, respectively.

An estimate of b, the intra-sire, intra-year regression of litter average 154-day weights on the inbreeding of the litter (126 litters, 34 sire-year groups) was —0.658 lb. for the Minnesota No. 1. For the Minnesota No. 2 it was —1.344 lb. (99 litters, 24 sire-year groups). These values of b are taken as indicators of what the effect of inbreeding on 154-day weights may be.

As estimates of actual rates of change (table 2), linear regression constants for herd performance on time in years were computed, using the data of table 3. The regression constants measure the slope of the lines in figures 1 and 2.

Discussion of Results

With reference to score, the selection differentials were usually larger in the males than in the females in the case of both lines. The two lines would be expected to increase in average annual score at about the same rate, but the actual rates estimated from the data of table 3

(see also figure 1) show that the Minnesota No. 1 increased at a rate slower than the expected rate, while the Minnesota No. 2 increased at a rate faster than the expected rate.

The limit for the score of any animal was 9. It would have been impossible for score to be increased beyond this point because 9 was

TABLE 1. SELECTION DIFFERENTIALS FOR SCORE AND WEIGHT AT 154 DAYS

Year	Score, Points			154-Day Weight, Lb.		
	Females	Males	Average	Females	Males	Average
			Minnesota No. 1			
1938	0.20	0.00	0.10	10.3	—12.2	—1.0
1939	0.68	1.15	0.92	6.9	—2.9	2.0
1940	0.27	0.11	0.19	7.8	—5.7	1.0
1941	0.57	0.26	0.42	12.3	—5.0	3.6
1942	0.45	0.53	0.49	9.7	14.7	12.2
1943	0.39	0.68	0.54	13.1	30.1	21.6
1944	0.38	1.35	0.86	8.7	37.0	22.8
1945	0.33	0.86	0.59	9.9	36.6	23.2
1946	0.66	1.38	1.02	16.9	33.8	25.4
1947	0.94	1.67	1.30	15.3	39.0	27.2
1948	1.20	1.44	1.32	17.7	38.2	28.0
Av.	0.55	0.86	0.70	11.7	18.5	15.1
			Minnesota No. 2			
1942	0.08	0.42	0.25	10.5	21.3	15.9
1943	0.33	1.11	0.72	1.0	26.6	13.8
1944	0.15	0.37	0.26	9.4	33.1	21.2
1945	0.46	1.32	0.89	8.1	11.9	10.0
1946	0.46	0.75	0.60	1.5	18.5	10.0
1947	0.39	1.19	0.79	2.1	—9.6	—3.8
1948	0.43	0.93	0.68	11.4	—2.3	4.6
Av.	0.33	0.87	0.60	6.3	14.2	10.2

set as the perfect score. As this limit is approached, the rate of increase in line average score is expected to decline. For this reason the regression of the annual means on time may appear curvilinear in nature. Selection for a character moderately high in heritability would be most effective in the early generations but less effective as the annual means approached the limit fixed by the scoring system. Assuming fairly constant selection pressure, the slope of a line fitted by the method of linear regression to the means of the first few years would be different from one fitted to the means of the last

few years or even of all the years. Inspection of the annual score averages of the Minnesota No. 1 (table 3) suggests that little, if any, progress was made after 1945, or after the first 8 years. When the rate of increase is estimated from the means of the first 8 years (1938–1945) it becomes 0.154 unit increase per year instead of 0.017 unit per year when all years are included. The 0.154 unit may then be compared with 0.177 unit per year, which is the rate of increase for the Minnesota No. 2 (table 2) during a comparable period of its development.

TABLE 2. THEORETICAL AND ACTUAL RATES OF CHANGE IN TWO PERFORMANCE TRAITS IN THE MINNESOTA NO. 1 AND NO. 2

Trait	G	I	b	s	H	m	Actual
			Minnesota No. 1				
Score	1.62	3.2	....	0.70	0.20	0.086	0.017
Wt. at 154 days	1.62	3.2	—.658	15.1	0.19	—.335	—1.278
			Minnesota No. 2				
Score	1.56	3.1	....	0.60	0.20	0.079	0.177
Wt. at 154 days	1.56	3.1	—1.344	10.2	0.20	—2.824	0.826

G, average interval between generations
I, increase in inbreeding per year
b, average change in the trait per unit of increase in inbreeding
s, selection differential
H, heritability estimate
Theoretical rate of change per year, $m=bI+sH/G$.

A practical difficulty in studying trends in the line average scores was the change in the method of measuring score. The change in 1944 from a maximum score of 54 points to a maximum score of 9 points made it necessary to seek some way of reducing the scores made prior to 1944 to the basis of the maximum of 9. If the "animal as a whole" score is consistently lower or higher than the score that would have been assigned on the basis of the scale in effect from 1944 on, then the yearly means for the period 1938–1943 inclusive are either uniformly higher or lower than they should be. If the means are too high, the slope of the regression line fitted to all of the data is reduced, and if the means are too low then the slope of the regression line is increased so that too much progress per year is indicated. This difficulty is less applicable to the Minnesota No. 2 because only the first 2 years, 1942 and 1943, are involved.

Along with the change in scoring system is the possibility of error introduced by the human element in assigning scores. It has not been possible for the scoring to be carried out by the same personnel

throughout the development of both lines. It is not difficult to conceive of the possibility that some of the annual variation in the line mean scores arises from the fact that scoring was done by different individuals. Also of importance, perhaps, is the fact that it was a practical impossibility to assign scores at a uniform weight. Differences in

TABLE 3. ANNUAL HERD AVERAGE SCORES AND WEIGHTS AT 154 DAYS

Year	Number of Animals	Average Score	Number of Animals	Average Weight at 154 Days
		Minnesota No. 1		
1938	155	7.57	174	174
1939	186	7.38	147	178
1940	208	7.72	200	191
1941	178	7.83	192	178
1942	214	7.65	214	192
1943	197	8.20	216	166
1944	84	8.24	110	174
1945	108	8.69	216	186
1946	144	7.54	144	184
1947	169	7.09	170	170
1948	226	7.89	113	157
1949	115	7.94	121	166
		Minnesota No. 2		
1942	49	6.78	70	159
1943	80	6.26	91	136
1944	77	6.86	78	178
1945	134	6.37	134	187
1946	144	8.08	173	170
1947	149	7.04	149	153
1948	66	8.06	140	163
1949	183	7.46	198	168

weight, as has been shown by Molln (1942), are slightly associated with differences in score, the heavier animals tending to receive the higher scores. It is possible that some of the differences in scores were actually caused by differences in weight at the time of scoring in spite of the best efforts of the persons doing the scoring not to be influenced by mere weight differences.

In average weight at 154 days the Minnesota No. 1 was expected to show a slight decline because the amount of progress expected from selection was less than the decline expected from inbreeding. It may be noted in table 2 that the Minnesota No. 1 did appear to decline in weight at 154 days, although at a faster rate than was predicted

(see also figure 2-A). If the formula for adjusting the weight records had a bias toward either an over- or under-correction, then the slope of the regression line would be affected. Such a bias in the No. 2 data would be of less importance because only 1 year was involved. As suggested by the value of *b* for the No. 2 (table 2), the No. 2 was expected to show even a more severe decline than the No. 1, but on the contrary the 154-day weights held up or perhaps increased nearly a pound per year.

Comparison of the two lines with respect to selection differentials

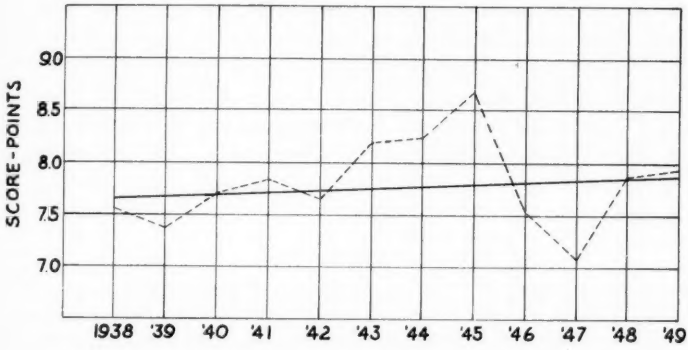

FIG. 1-A. ANNUAL AVERAGE CONFORMATION SCORE — MINNESOTA NO. 1.

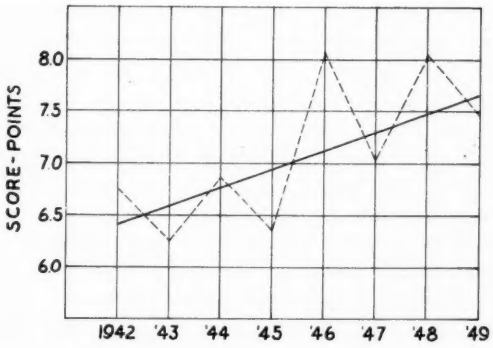

FIG. 1-B. ANNUAL AVERAGE CONFORMATION SCORE — MINNESOTA NO. 2.

for 154-day weight (table 1) shows that different tendencies existed as to when most selection was practiced. Selection differentials tended to be larger in the Minnesota No. 2 in the early years and smaller in the later years. The opposite condition is noted in the No. 1. A backcross was made to the Poland-China early in the development of the No. 2 for the purpose of improving the growth rate (Winters *et al.*, 1948). About one half of the 1944 pig crop was produced from backcross matings. The growth rates in the No. 2 for 1944 and 1945 (table 3) were the highest at any time in the development of the

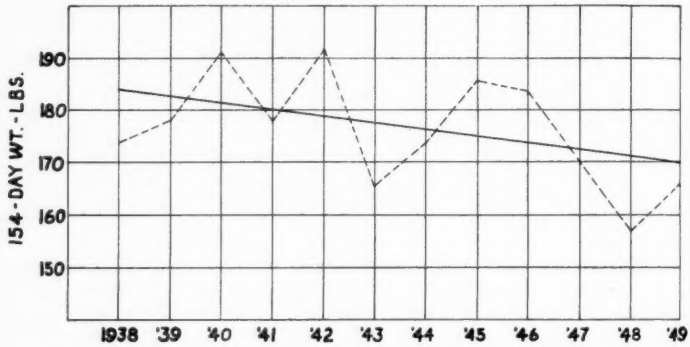

FIG 2-A. ANNUAL AVERAGE 154-DAY WEIGHT-MINNESOTA NO.1.

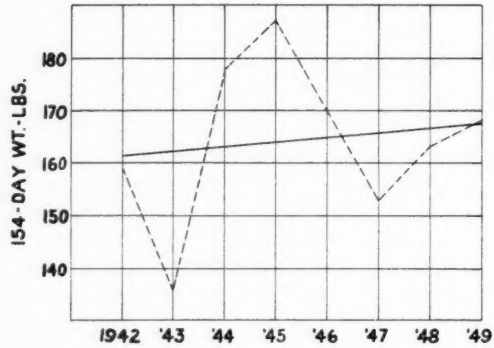

FIG. 2-B. ANNUAL AVERAGE 154-DAY WEIGHT-MINNESOTA NO.2.

line. The backcross may have introduced some more genes which were favorable to a higher growth rate at the same period when more selection was being practiced for growth rate. More early selection for growth rate in the No. 2 may have gotten it off to a better start. The No. 2 was expected to show a more severe decline than the No. 1, but the No. 2 actually tended to increase slightly. By contrast the No. 1, in which selection for growth rate was rather slight in the beginning years, showed a more severe decline than was expected.

Reasons why time trends in performance can be misleading as measures of genetic change have already been pointed out by Dickerson (1951). The sources of error he mentioned were time trends in nutrition, disease, management and climate. Furthermore, there may be rather large samplying errors associated with estimates of actual time trends because the annual averages are usually relatively few in number. For this reason one should not ascribe too much importance to agreement of actual and expected rates. Yet time trends in performance are about the only measures of improvement, even though the trends cannot be reduced to simple genetic trends only.

Summary

The amount of selection, as measured by the average deviation of selected parents from their generation averages in score as to market desirability and growth rate (weight at 154 days of age), was determined in the Minnesota No. 1 and Minnesota No. 2, two inbred lines in the Minnesota swine breeding project. The average annual selection differentials for the No. 1 and No. 2, respectively, in score were 0.70 point and 0.60 point on the basis of 9 points being a perfect score. For weight at 154 days the selection differentials were 15.1 pounds and 10.2 pounds for the No. 1 and No. 2 respectively. The herd average scores for both lines were expected to increase when predicted from the selection differentials and the heritability estimates. That both lines showed some improvement was fairly evident from the time trends in herd average score. It was also predicted, using the selection differentials, heritability estimates for 154-day weights and rate of inbreeding, that the lines would show a decline in growth rate because the amount of selection practiced did not appear sufficient to offset the decline expected to result from the inbreeding carried on. The Minnesota No. 1 did decline in herd average 154-day weight, but the No. 2 appeared to be increasing slowly at a rate just less than 1 pound per year.

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THE GROWTH OF DUROC SUCKLING PIGS RAISED IN DRYLOT[1]

R. P. Forshaw, Helen M. Maddock, Paul G. Homeyer and Damon V. Catron[2]

Iowa Agricultural Experiment Station

FUNDAMENTAL studies dealing with the pig's development during gestation and lactation continue to receive considerable attention. Comparisons between groups within the same experiment usually meet the needs of the investigator; however the value of reference growth curves in such work has not been fully investigated.

A number of pre-weaning growth curves for swine have been published. They are of limited usefulness under present conditions for one or more of three reasons. (1) Many deal with bacon breeds fed under European conditions. (2) The conditions under which the sows were maintained during gestation and/or lactation are not stated. Because most nutritional studies are conducted under definitely stated conditions, i.e., pasture or drylot or in a combination of the two, it is important to know the details of treatment and management under which the individuals used in constructing growth curves were maintained. (3) No measure of variation in the birth and weekly live weights is given. It is therefore not possible to determine the uniformity of the populations from which the growth curves were constructed.

Mumford *et al.* (1923) have presented a growth curve for suckling pigs up to 8 weeks of age based upon group weighings of 15 litters (approximately 100 pigs). Russell (1925) constructed a growth curve using approximately 1000 pigs. This has been discussed by McKenzie (1926). Richter (1928) at Göttingen studied data from the Ruhlsdorf Experiment Station on the average birth and weekly weights of suckling pigs based upon 62 litters of Landschwein and 63 litters of Edelschwein.

Berge (1936), of the Agricultural College of Norway, studied the growth of 791 pigs from 79 litters. The distribution by breeds was as follows: 288 from 30 Yorkshire litters, 447 from 44 Landrace litters, and 56 from five Landrace $\times$ Yorkshire litters. Based upon 620

[1] Journal Paper No. J-2148 of the Iowa Agricultural Experiment Station, Animal Husbandry Department. Project 959.

[2] The authors acknowledge the assistance of Mr. Don Quinn, Swine Nutrition Farm foreman and his associates.

pigs which lived to weaning at 56 days of age, Berge has presented a growth curve using average birth and weekly live weights.

Whatley and Quaife (1937) cite 10 sources of data on pre-weaning weights of swine, nine of which are for breeds found almost entirely in Europe. Ittner and Hughes (1938) have proposed a normal growth curve for pigs from birth to 28 weeks of age using bi-weekly weighings of 171 pigs before weaning and 286 after weaning. Ashton and Crampton (1943) have published a pre-weaning growth curve for bacon type pigs based upon the birth and weekly live weights of 140 pigs. With each average weight these authors have given the standard deviation as a measure of the variation in the population.

Birth weight as a factor in determining weaning weight of pigs has been studied by a number of investigators. Kuhlman (1928), working with the litters of 227 aged sows and 207 yearling sows, obtained a correlation of 0.49 between birth and weaning weight. Baker (1939), using the data from 117 pigs from 36 litters at the Nebraska station and 387 pigs from 79 litters at the Iowa Station, obtained correlations of 0.44 and 0.48 between birth and weaning weight. Kuhlman (1928) reported that a one-half pound advantage in birth weight was accompanied by 4 to 5 pounds greater weight at weaning. The regressions of weaning weight on birth weight reported by Baker (1939) are 5.7 and 6.8. Weaver and Bogart (1943) reported an advantage of approximately 7 pounds at weaning for each pound increase in birth weight.

By means of paired litters farrowed at approximately the same time and divided into two groups of pigs, one of which was left with its own mother and the other transferred to a second sow in exchange for a similar group, Donald (1939) studied the relative importance of nutrition and breeding in the growth of suckling pigs. In all, 20 litters were used in this study. It was concluded that the most important factor in the growth of suckling pigs is the milk production of the sows.

The purpose of the present study was threefold: (1) to construct a reference growth curve for suckling Duroc pigs raised under dry-lot conditions, (2) to study the birth and weekly live weights to weaning of pigs classified as light, medium or heavy at weaning (8 weeks), and (3) to study the relationship between birth and weaning weights.

Materials and Methods

The birth weights and weekly live weights of 1296 pigs from 191 litters were available for this study. These represented all litters produced in gestation-lactation nutrition studies from the spring of 1947

to the spring of 1950 except those from one experiment which involved repeated heart punctures of the pigs. All but 38 of the litters were from gilts. Pigs which died prior to weaning were not included in this study.

The pigs were purebred Durocs. No sows were purchased during the period under study, all the sows having descended from the original foundation herd of 12 gilts and a boar, purchased in 1945, and 7 pure-bred boars purchased thereafter. The individuals in the herd could be classified as medium in type. Gilts for the breeding herd were selected on the basis of dam's performance, their gains and type.

The sows and litters were raised on either dirt drylot or concrete during gestation and on concrete during lactation. By 1950 some of the sows whose litters were included represented the fourth generation raised entirely in drylot. The rations fed to the sows were composed mainly of corn and soybean oil meal, including sources of animal protein, alfalfa meal, minerals including trace minerals, and water- and fat-soluble vitamins. The rations contained from 14 to 16 percent of protein and met the N.R.C. allowances for other nutrients. In most gestation-lactation experiments no significant differences due to rations were found. None of the pigs were creep-fed, but they had access to the sow's ration.

Using all pigs, the average and standard deviations were calculated for the birth and weekly live weights. In order to study the previous growth rate of pigs which weaned at different weights, the pigs were divided into three groups. This grouping was done solely on the basis of weaning weight and placed approximately one-third of the total pigs in each group. Berge (1936, pp. 88–91 especially) used similar methods for studying the growth of pigs to 90 kg. In statistical terms, the final weight is the independent variable. The purpose is to learn differences in prior performance of pigs which end in different weight classes. This is not the same as grouping them on birth weight and studying the subsequent performance of pigs which are initially in different weight classes. The weight ranges of the three groups were as follows: Group 1, less than 24.6 lbs.; Group 2, 24.6 to 32.0 lbs.; and Group 3, more than 32.0 lbs. Within each group the weekly gains were expressed as a fraction of the body weight of the pigs at the beginning of each period. This was done to determine whether the pigs which were lighter than average at weaning had made poorer gains relative to initial body weight than those which were heavier than average.

The pigs were classified also according to birth weight. Growth

curve data were calculated for the separate groups. In all, 10 classes were used as shown in table 4. Using all pigs, the correlation between birth weight and weaning weight, and the regression of weaning weight on birth weight were calculated.

Results and Discussion

The average birth and weekly live weights are shown in figure 1. These are the data in the last column of table 1. This table also shows, for comparison, seven previously published sets of data. The number in each group, the birth weights and the weekly live weights, when the pigs were classified according to weaning weight, are given

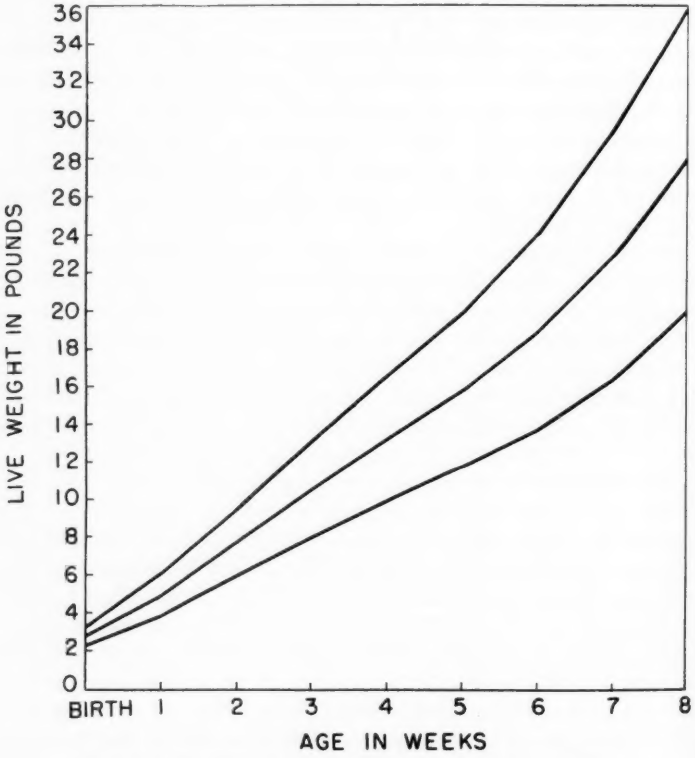

Figure 1. Growth of Duroc pigs from birth to weaning. (Upper and lower lines indicate ±1 Standard Deviation)

TABLE 1. A COMPARISON OF GROWTH CURVES FOR SUCKLING PIGS

Age of Pig	Bacon Type					Lard Type				
	Macdonald College Ashton & Crampton (1944)		Norway Agr. College Berge (1936)	University of Göttingen Richter (1928)		U.S.D.A. McKenzie (1926)	Missouri Agr. Exp. Sta. Mumford *et al.* (1923)	California Agr. Exp. Sta. Ittner & Hughes (1938)	Iowa Agr. Exp. Sta.	
				Land-schwein	Edel-schwein					
	Wt.	s[1]	(pounds)						Wt.	s[1]
Birth	2.7	0.4	2.8	2.8	2.6	2.6	1.8	3.2	2.8	0.5
1 week	5.3	1.4	5.0	5.3	4.7	5.7	8.5	....	5.0	1.1
2 weeks	8.5	1.8	8.0	7.8	7.3	8.5	10.5	7.5	7.8	1.8
3 weeks	11.9	2.3	10.7	10.4	9.6	11.1	14.5	....	10.7	2.6
4 weeks	15.1	2.9	13.3	13.0	11.8	13.7	16.8	13.1	13.4	3.3
5 weeks	18.3	3.7	16.6	15.8	14.5	16.4	20.8	....	15.9	4.1
6 weeks	21.9	4.5	20.5	19.6	17.4	19.9	22.0	20.0	19.0	5.1
7 weeks	25.8	4.9	25.3	23.2	21.2	23.6	27.0	....	23.0	6.5
8 weeks	30.5	6.1	30.3	27.8	25.6	27.7	30.0	29.4	28.1	8.1

[1] Standard deviation of a single weight.

in table 2. In table 3 are the weekly gains expressed as a fraction of the body weight of the pigs at the beginning of each weekly period.

Table 2 indicates that the pigs which were lighter at weaning time had averaged lighter at birth. They were not only smaller at birth,

TABLE 2. BIRTH AND WEEKLY LIVE WEIGHTS OF PIGS CLASSIFIED ACCORDING TO WEANING WEIGHT

Group	I	II	III
Weight range (lb.)	<24.6	24.6–32.0	>32.0
Number of pigs	432	452	412
Age		(pounds)	
Birth	2.6	2.8	3.0
1 week	4.2	5.0	5.8
2 weeks	6.5	7.8	9.1
3 weeks	8.7	10.6	12.7
4 weeks	10.7	13.4	16.2
5 weeks	12.2	15.9	19.9
6 weeks	13.9	18.9	24.5
7 weeks	16.2	22.9	30.4
8 weeks	19.1	28.1	37.4

TABLE 3. AVERAGE WEEKLY LIVE WEIGHT GAINS EXPRESSED AS A FRACTION OF BODY WEIGHT AT START OF WEEKLY PERIOD

Group	I	II	III
Weekly periods			
First	0.615	0.786	0.933
Second	0.548	0.560	0.569
Third	0.338	0.359	0.396
Fourth	0.230	0.264	0.276
Fifth	0.140	0.187	0.228
Sixth	0.139	0.189	0.231
Seventh	0.166	0.212	0.241
Eighth	0.179	0.227	0.230

but they also made smaller weekly gains both in absolute amounts and as fractions of their birth weights (table 3) than the heavier weaning pigs.

The correlation between birth weight and weaning weight at 8 weeks of age was 0.46 when the 1296 pigs were analyzed as a single population. A correlation of 0.46 means that 21.2 percent of the variation in weaning weight was linearly associated with birth weight. This correlation can be considered as a weighted average of 0.31 on an

TABLE 4. AVERAGE BIRTH AND WEEKLY WEIGHTS OF SUCKLING PIGS CLASSIFIED ACCORDING TO BIRTH WEIGHT

Weight range (lb.)	<1.76	1.76–2.00	2.01–2.25	2.26–2.50	2.51–2.75	2.76–3.00	3.01–3.25	3.26–3.50	3.51–3.75	>3.75
					(pounds)					
Birth	1.5	1.9	2.2	2.4	2.6	2.9	3.1	3.4	3.6	3.9
1 week	3.1	3.5	4.0	4.5	4.6	5.1	5.6	5.9	6.3	6.6
2 weeks	5.0	5.7	6.4	7.2	7.3	7.9	8.6	8.9	9.6	10.0
3 weeks	6.8	7.7	9.1	10.0	10.0	10.8	11.8	12.1	12.8	13.6
4 weeks	8.5	9.7	11.6	12.6	12.6	13.5	14.6	15.0	16.1	17.2
5 weeks	10.2	11.6	13.6	14.9	15.1	15.9	17.5	18.2	19.2	20.9
6 weeks	11.7	13.7	16.0	17.7	18.0	19.0	21.0	22.1	22.9	25.1
7 weeks	14.0	16.5	19.1	21.4	21.8	23.0	25.5	27.1	27.5	30.6
8 weeks	17.1	20.0	23.3	26.2	26.5	28.1	31.2	32.8	33.5	37.3

intra-litter basis (1104 degrees of freedom) and 0.54 between litters (189 degrees of freedom). The 0.31 and the 0.54 are significantly different (P=0.01). The values found in this study are in good agreement with previously reported correlations. The regression of weaning weight on birth weight was 7.78 pounds. This figure is near the average of four previously reported values.

Summary and Conclusions

(1) A growth curve for suckling Duroc pigs raised under drylot conditions is presented. The birth and weekly live weights up to weaning at 8 weeks of age of 1296 pigs were used.

(2) The correlation of 0.46 between weaning weight and birth weight was highly significant (P=0.01).

(3) On the average, a difference of 1 pound in weight at birth was accompanied by 7.78 pounds difference at weaning (56 days).

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THE NUTRITIVE VALUE OF WOOD CHARCOAL FOR PIGS

ROBERT TOTUSEK and W. M. BEESON [1]

Purdue University Agricultural Experiment Station [2]

CHARCOAL is often included in commercial mineral mixtures and is frequently added to concentrate mixtures, especially for swine and poultry. Furthermore, the practice is common among many farmers to routinely provide charcoal, wood ashes or coal for their hogs. Charcoal is said to be desirable in mineral mixtures to prevent caking, to increase palatability and to produce a desirable and uniform color to improve its appearance. The use of charcoal in animal feeding is also sometimes recommended as a treatment for diarrhea and as an adsorbent of gases and detrimental products in the gastro-intestinal tract.

Henry (1889) reported an experiment in which the addition of ground bone or hardwood ashes to the ration doubled the amount of ash and breaking strength of the thigh bone, increased corn consumption 25 percent, tripled water intake and resulted in the saving of about 50 pounds of corn per 100 pounds gain. Two additional trials by Henry (1890) yielded similar results. Evvard *et al.* (1925, 1927) found small differences in favor of feeding charcoal to pigs. Thompson (1932, 1933) observed 14 percent faster gains in one trial and 8 percent slower gains in another trial when charcoal was added to a basal swine ration which contained no supplemental minerals. Lentz (1932) reported that wood charcoal is useful in the treatment of scours in pigs. Frolich and Luthge (1934) observed larger weight gains in pigs receiving charcoal as compared to the control ration. Grummer *et al.* (1951) reported no growth stimulation in two trials when pigs received soft or hard coal and feed efficiency was lower and cost of gain higher for pigs fed coal.

Willman and Morrison (1947) conducted seven trials in which the addition of one percent charcoal was compared to an otherwise satisfactory ration. In six of the trials, charcoal was also fed at a level of 3 percent of the ration. Differences in gains, feed consumption and feed efficiency were small and not statistically significant.

[1] The authors wish to express their appreciation to the National Mineral Feeds Association, Inc., 212 Equitable Bldg., Des Moines 9, Iowa for establishing a grant to support this project, and to the several charcoal manufacturers for furnishing adequate amounts of charcoal for this research.

[2] Contribution from the Department of Animal Husbandry, Journal Paper No. 653, Purdue University Agricultural Experiment Station, Lafayette, Indiana.

Almquist and Zander (1940) reported that a synthetic chick diet adequate for normal growth but without margins of safety in vitamin content was rendered deficient in vitamins A, K and riboflavin, and the gizzard anti-erosion factor by the addition of 2 percent adsorbing charcoal.

However, little is known about the actual value of charcoal in the ration of swine, and very few reports concerning the effect of charcoal additions to present-day well balanced rations have appeared in the literature. This research was initiated, therefore, with the following objectives in view: (1) to determine the effect of charcoal on growing-fattening pigs, (2) to determine the factor(s) responsible if any effects were noted, (3) to determine the effect of charcoal on the consumption of mineral mixtures fed free choice and (4) to determine quantitatively the mineral elements contained in charcoal.

TABLE 1. COMPOSITION OF SEMI-PURIFIED DIET FED IN TRIALS I AND II

Ingredient	Percent
Casein	23.50
Dextrose (cerelose)	63.57
Corn oil	5.00
Cellu flour	2.00
Mineral mix [1]	5.20
Vitamin supplement [2]	0.13
APF (Lederle No. 5)	0.50
	100.00

[1] Heinemann *et al.* (1946).

[2] The vitamin supplement provided the following vitamins (amounts are per pound of total diet):

Thiamin hydrochloride	4.0 mg.	Vitamin K (Menadione)	1.0 mg.
Riboflavin	1.4 mg.	Folic acid	0.3 mg.
Niacin	9.0 mg.	Tocopherols (mixed, 34%)	100.0 mg.
Calcium pantothenate	4.5 mg.	Vitamin A (from fish liver oil)	1050.0 I.U.
Pyridoxine hydrochloride	1.6 mg.	Vitamin D (from fish liver oil)	140.0 I.U.
Choline chloride	200.0 mg.		

Experimental Procedure

First Feeding Trial

A semi-purified diet was employed as the basal in the initial trials, so that if charcoal exerted any apparent effect upon the pigs, it would be less difficult to determine the exact constituent(s) responsible. The composition of the basal ration is given in table 1. Vitamins were pre-mixed with casein and added, together with the mineral mix, to

the complete diet. Mixtures were made in sufficient quantities to last about 1 week. A one-week adjustment period was allowed in changing from a natural grain ration to the synthetic type diet to prevent digestive disturbances.

Ten weanling Duroc barrows of related breeding were paired on the basis of initial weights and confined to individual adjacent pens with raised screen floors. Pens were washed daily. Diets and water were supplied *ad libitum* in individual metal troughs. One pig of each pair was fed the basal ration, while the other pig of each pair received 0.5 percent charcoal in place of a like amount of dextrose. Charcoal used was a hardwood No. 36 grade product, with a texture resembling granulated sugar, which had been carbonized from oak primarily and a small amount of hickory.

Individual pig weights and feed data were recorded at 7 day intervals. Careful observations were made during the progress of the experiment on the health and amount of scouring evidenced by each pig. Blood samples were taken after 98 days and analyzed for hemoglobin and red blood cells. At the time of slaughter each pig was carefully examined in an attempt to detect any possible gross anatomical lesions, and samples of liver were obtained and analyzed for moisture and fat.

Second Feeding Trial

With several exceptions this trial was essentially a repetition of the previous one. Individual concrete pens bedded with straw were used instead of raised screen floors, since this trial was conducted during cold weather instead of in the summer and it was doubted that this change in procedure would bias the experiment. Equal numbers of barrows and gilts were used in this trial, rather than barrows alone. Six pairs of pigs (one more pair than in the previous trial) were paired on the basis of litter as well as sex and weight. In a further attempt to detect any pathological conditions possibly resulting from feeding or not feeding charcoal, histological studies of the kidneys and livers were made in this trial. Except for the brief differences mentioned, the experimental procedure in this trial, including the composition of the synthetic-type diet and the type of charcoal used, was identical to that of the previous one.

Third Feeding Trial

Sixty purebred Duroc pigs which had been raised on pasture with access to a good ration were stratified on the basis of sex, weight

and litter and randomly allotted into six lots of 10 pigs each. A natural all-plant basal ration, fortified with vitamins and minerals and an antibiotic, was used in place of a synthetic diet in this trial. The composition of the basal and experimental grain rations and mineral mixes is given in table 2. It may be noted that an incomplete factorial design was used. The initial protein level of 20 percent was reduced with increasing weight of the pigs according to recommendation of the National Research Council (Hughes *et al.*, 1950). Both the basal grain ration and basal mineral mix were designed without animal products to allow trace minerals in charcoal and supplemental trace minerals to exert any possible effect. Charcoal and trace minerals were added to the basal mineral mix, both individually and together (Lots 2, 3 and 4). The amounts of trace minerals fed are given in table 2. Charcoal was also added to the basal grain ration at levels of 0.5 and 3 percent (lots 5 and 6), replacing an equivalent amount of corn. The same type and grade of charcoal as used in the first two trials, No. 36 hardwood, was used again.

Pigs were confined to concrete floors. Automatic water fountains were located outdoors and separate self-feeders for the mineral mix and grain ration were inside. Individual pig weights and feed data were recorded at 14-day intervals. Each lot of pigs was removed from experiment at an average weight of 200 pounds, or shortly thereafter.

Mineral Analysis of Charcoal

First, three separate spectrographic analyses were obtained on each of two types of charcoal, hardwood No. 36 (which was used in the feeding trials) and softwood No. 80 grade. The softwood charcoal had been carbonized from resinous pine wood by destructive distillation and was of much finer texture than the hardwood No. 36 product. Although it was recognized that a spectrographic analysis would not yield precise quantitative data, this method was employed first in order to obtain quickly an overall picture of the approximate mineral composition of charcoal. In addition, these approximate values would be helpful in making more exact chemical determinations.

It was decided to analyze charcoal chemically for only six elements. Of the 13 mineral elements usually considered essential, sulfur is required as a constituent of protein; magnesium and potassium are always adequate in swine rations; sodium, chlorine and iodine are routinely provided as iodized salt; and the value of supplemental zinc in swine rations has never been demonstrated (Maynard, 1951). With

these considerations in mind, the remaining mineral elements of the essential 13 are calcium, phosphorus, manganese, iron, copper and cobalt. The quantity of each of these was determined in the two charcoals, hardwood No. 36 and softwood No. 80. All determinations were

TABLE 2. COMPOSITION OF RATIONS FED IN TRIAL III

Ingredient		Lot 1	2	3	4	5	6
Grain ration							
Ground yellow corn	%	64.4	64.4	64.4	64.4	63.9	61.4
Soybean oil meal, solvent	%	30.0	30.0	30.0	30.0	30.0	30.0
Dehydrated alfalfa meal	%	5.0	5.0	5.0	5.0	5.0	5.0
Cod-liver oil (2250-A, 300-D)	%	0.1	0.1	0.1	0.1	0.1	0.1
Aurofac (Lederle)[1]	%	0.5	0.5	0.5	0.5	0.5	0.5
Charcoal	%	....	....	....	....	0.5	3.0
Supplemental vitamins							
Riboflavin	mg./lb.	0.8	0.8	0.8	0.8	0.8	0.8
Niacin	mg./lb.	5.0	5.0	5.0	5.0	5.0	5.0
Calcium pantothenate	mg./lb.	4.5	4.5	4.5	4.5	4.5	4.5
Mineral mix (free choice)							
Tricalcium phosphate	%	60.0	51.0	58.34	49.59	60.0	60.0
Calcium carbonate	%	20.0	17.0	19.45	16.53	20.0	20.0
Iodized salt	%	20.0	17.0	19.45	16.53	20.0	20.0
Charcoal	%	....	15.0	....	14.59	....	....
Trace minerals[2]	%	....	....	2.76	2.76	....	....

[1] Guaranteed potency of 1.8 gm. aureomycin and 1.8 mg. vitamin B_{12} per pound.

[2] $MnCl_2 \cdot 4\ H_2O$—299.2 gm., $CuSO_4$—171.9 gm., $Fe_4(P_2O7)_3 \cdot 9\ H_2O$—735.7 gm., $CoCO_3$—27.5 gm., and ZnO—16.9 gm. Amounts of trace minerals consumed were as follows (expected intake was based on the assumption that the mineral mix would be consumed at an average rate of 1% of the total feed intake).

	Expected Intake	Actual Intake (p.p.m. of total feed consumed)	
		Lot 3	Lot 4
	p.p.m.	p.p.m.	p.p.m.
Manganese	25	25.8	30.5
Copper	15	15.4	18.3
Iron	40	41.2	48.8
Cobalt	3	3.1	3.7
Zinc	3	3.1	3.7

made in duplicate. Calcium and manganese were determined by methods outlined by the Association of Official Agricultural Chemists (1945), phosphorus by a modification of the method of Fiske and Subbarow (1925), iron by the method of Jackson (1938), copper by the method of Hoste (1950) and cobalt by a modified combination of the methods of Kidson and Askew (1940) and Sandell (1944).

Results and Discussion

Three Feeding Trials

Gain and feed data for Trials I, II and III are summarized in tables 3 and 4.

The inclusion of charcoal in either synthetic or natural rations did not significantly influence the growth rate of pigs. Although synthetic diets had not previously been employed in charcoal studies, these results are in agreement with experiments on natural rations for pigs

TABLE 3. THE EFFECT OF CHARCOAL ON GROWTH, FEED CONSUMPTION AND FEED EFFICIENCY OF GROWING-FATTENING PIGS. TRIALS I AND II

Items Considered	Trial I		Trial II	
	Basal	Basal Plus 0.5% Charcoal	Basal	Basal Plus 0.5% Charcoal
No. of pigs	5[1]	5	6	6
No. of days on experiment	105	105	96	96
Av. initial wt., lb.	26.8	27.6	34.2	33.7
Av. final wt., lb.	186.8	183.3	201.2	191.8
Av. daily gain, lb.	1.48	1.48	1.74	1.65
Av. daily feed, lb.	4.23	4.48	5.08	5.07
Feed per cwt. gain, lb.	286.7	302.1	292.0	307.9

[1] One pig was removed from the experiment on the 77th day due to a sudden loss of weight and appetite and inability to stand alone.

reported by Willman and Morrison (1947) and Evvard *et al.* (1925, 1927). Grummer (1951) observed no differences in rate of gain of pigs which could be attributed to the feeding of hard or soft coal. Heuser (1938), Almquist and Zander (1940), and Mangold and Damkohler (1936) similarly observed no differences when charcoal was fed in natural rations to growing chicks. In the third feeding trial, pigs receiving charcoal as 0.5 to 3.0 percent of a natural ration (Lots 5 and 6) gained more slowly than control pigs. The differences approached statistical significance. There is a possibility that the presence of charcoal was responsible for the lowered gains of Lots 5 and 6 in Trial III. However, it would seem that if the charcoal were responsible, whether by energy dilution, vitamin adsorption or the presence of toxic factors, increasing the level from 0.5 percent to 3.0 percent should further depress gains. This did not occur.

Henry (1889, 1890) found that weight gains of pigs were increased about 20 to 50 percent by the feeding of wood ashes. These results

are not confirmed by the research herein reported. The conflict in results can probably be explained by differences in experimental procedure, since Henry added wood ashes to a basal ration consisting solely of corn, while in the three trials reported here charcoal was added to well balanced rations.

The lack of any marked effect of charcoal on feed efficiency or feed consumption in these trials essentially agrees with previous reports,

TABLE 4. THE EFFECTS OF CHARCOAL AND/OR TRACE MINERALS ON RATE OF GAIN, FEED CONSUMPTION, FEED EFFICIENCY AND MINERAL MIX CONSUMPTION, TRIAL III

(10 pigs per lot)

Lot and Treatment	Days on Feed	Av. Initial Wt. lb.	Av. Final Wt. lb.	Av. Daily Gain [1]	Av. Daily Feed	Feed per 100 lb. Gain	Mineral Mix Consumed [2]
				lb.	lb.	lb.	%
1 Basal ration	98	34.2	200.9	1.70	6.24	367.0	1.15
2 15% charcoal in mineral mix	98	36.8	200.6	1.67	6.52	390.1	0.99
3 Trace minerals in mineral mix	102	35.3	201.2	1.63	6.14	377.6	1.03
4 Charcoal and trace minerals in mineral mix	99	35.5	202.8	1.69	6.64	392.9	1.22
5 0.5% charcoal in basal	104	35.6	200.4	1.58	6.05	381.9	1.05
6 3.0% charcoal in basal	105	34.1	201.0	1.59	5.93	372.8	0.70

[1] Least significant difference at 5% level=0.13 pound.
[2] Expressed as % of total ration. In Lots 2 and 4, 15% of the mineral mix consisted of charcoal.

although Henry (1889, 1890) found that wood ashes saved 20 percent corn and increased corn consumption 25 percent. This again was probably due to the deficient nature of the all-corn basal ration used by Henry.

Differences in mineral mix intake due to the inclusion of charcoal and/or trace minerals were not marked and could not be attributed to the treatments on the basis of only one trial. Thompson (1932) found that charcoal or wood ashes in the mineral mix doubled or tripled consumption, and coal increased consumption of minerals more than five fold. However, in that experiment charcoal completely replaced bonemeal or limestone in mixes of two parts bonemeal or limestone and one part salt. Therefore, charcoal composed 66 percent

of the mineral mix as compared to only 15 percent in this study and would not only have more opportunity to exert a palatability effect but would also need to be consumed in much larger amounts as the only source of supplemental minerals other than salt.

Pigs receiving 3.0 percent charcoal in the grain ration consumed 39 percent less mineral mix than the control lot. It would appear that charcoal in the ration at this level furnishes a sufficient amount of mineral matter to decrease the intake of supplemental minerals to some extent. Grummer *et al.* (1951) did not find any such mineral sparing effect when soft or hard coal was fed to pigs, even though the daily consumption of coal was similar to the charcoal intake of Lot 6 in this experiment. Evidently coal does not furnish as much mineral matter as the charcoal that was used in this experiment.

Trace minerals in the mineral mix not only failed to appreciably influence the consumption of minerals, but also had no apparent effect on the rate of gain. This is not in agreement with recent investigations at other experiment stations. Speer *et al.* (1950) and Klosterman *et al.* (1950) reported increased gains with the addition of trace minerals to drylot rations containing animal proteins, and Noland *et al.* (1951) obtained a significant response when trace minerals were added to an all-plant drylot ration. Earlier results reported by Longwell and Severson (1944) are in agreement with findings in this experiment. Differences in results may be due to different levels and/or combinations of trace minerals fed, or perhaps to differences in the mineral content of natural feeds grown at different locations in the country.

The hemoglobin, erythrocyte, liver fat and liver moisture values determined in Trials I and II, as well as histological observations on the liver and kidney (Trial II), were all very similar and within the normal physiological range, as would be expected for groups of pigs with little difference in performance and health. Similarly, no gross anatomical lesions were found at the time of slaughter. Some scouring was noted in Trial I, and a comparison between pigs with and without charcoal in the ration indicated a slight advantage for charcoal feeding (19 versus 12 pig days of scouring), although the data were not sufficient to justify any conclusions. Both Lentz (1932) and Mangold (1936) reported that wood charcoal was effective in treating scours in pigs. Heuser (1938) and Mangold and Damkohler (1936) also observed a beneficial effect of wood charcoal on diarrhea in poultry. In Trial III a loss of hair in the region of the rump and ham was noted on four pigs receiving charcoal and to a very slight extent on one basal pig. This loss of hair may have been due to the adsorption by charcoal of a nutritional factor(s) from the intestinal tract. Alm-

quist and Zander (1940) reported that a chick diet adequate for normal growth, but without margins of safety in vitamin content, was rendered deficient in vitamins A and K, riboflavin and the gizzard factor by the addition of 2 percent charcoal to the diet. However, the charcoal used by these workers at a 2 percent level was an activated type, which has a very much greater adsorptive capacity than the regular charcoal used in this trial at a level of only 0.5 percent. Furthermore, growth was not significantly affected in the trial in which hair loss occurred, as might be expected with adsorption of nutritional factors.

TABLE 5. A PARTIAL CHEMICAL ANALYSIS OF THE MINERALS IN TWO CHARCOALS

	Type of Charcoal			
	Hardwood No. 36 Grade		Softwood No. 80 Grade	
Mineral	Charcoal Basis [1]	Ash Basis [2]	Charcoal Basis [1]	Ash Basis [2]
Calcium, %	5.24	44.41	5.20	54.17
Phosphorus, %	0.034	0.29	0.049	0.51
Manganese, %	0.102	0.86	0.185	1.93
Iron, %	0.047	0.40	0.044	0.46
Copper, %	0.0084	0.07	0.0074	0.08
Cobalt, p.p.m.	0.35	2.97	9.0	93.8

[1] These values are expressed as a proportion of the charcoal.
[2] These values are expressed as a proportion of the ash. Hardwood No. 36 charcoal contained 11.8% ash; softwood charcoal contained 9.6% ash.

Mineral Analysis of Charcoal

The spectrographic analyses indicated that all of the 14 elements which were checked (calcium, phosphorus, manganese, iron, copper, cobalt, sodium, magnesium, zinc, potassium, molybdenum, aluminum, silicon and boron) were present in at least trace amounts in both types of charcoal. Calcium is the only element which appeared to be present in relatively large amounts, although silicon was present in appreciable quantity. A detailed chemical analysis for calcium, phosphorus, manganese, iron, copper and cobalt indicated the composition summarized in table 5. Although containing about 19 percent less total ash, the softwood No. 80 charcoal contained higher amounts of phosphorus, manganese and cobalt than hardwood No. 36, and only slightly smaller quantities of calcium, iron and copper. Consequently, when the minerals are expressed as a proportion of the ash, softwood No. 80 charcoal was highest with respect to all 6 minerals.

Hardwood No. 36 charcoal was fed in all three feeding trials, at a

level of either 0.5 or 3.0 percent. The influence of charcoal at these levels upon the mineral content (6 elements) of the total ration was calculated. These contributions of charcoal were then compared to the requirements of pigs for calcium and phosphorus (Hughes *et al.*, 1950), manganese (Grummer *et al.*, 1950), and iron and copper (Maynard, 1951). The inclusion of hardwood No. 36 charcoal at a level of 0.5 percent of the ration did not significantly increase the content of the 6 elements. However, at a level of 3 percent, charcoal furnished appreciable quantities of calcium (28 percent of the requirement), manganese (76 percent of the requirement), iron (29 percent of the requirement) and copper (48 percent of the requirement). It is not surprising then, since charcoal at a level of 3.0 percent contributed significant amounts of certain minerals, that the consumption of mineral mix by Lot 6 in Trial III was lowered. The failure of charcoal to influence the performance of pigs in the feeding trials was possibly due to the fact that sufficient minerals were already present in the basal ration or possibly the minerals in the charcoal are not utilized by the pig. If added to a deficient ration charcoal might have a value as a source of minerals. In that case its use would be determined by comparative price values.

Summary

1. The addition of charcoal to well balanced synthetic or natural rations at levels of 0.5 or 3 percent of the ration had no significant effect on growing-fattening pigs.

2. Mineral mix consumption was not increased by the inclusion of charcoal in the mix at a level of 15 percent.

3. Charcoal, such as was used in the feeding trials (hardwood No. 36), furnished significant amounts of calcium, manganese, iron and copper when fed at a level of 3 percent of grain ration. This may have been responsible for the lowered intake of mineral mix which was observed.

4. Softwood No. 80 charcoal contained higher amounts of certain essential minerals than hardwood No. 36 charcoal.

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THE QUALITY OF PROTEIN OF NORMAL AND HIGH PROTEIN CORN FOR GROWING SWINE[1,2]

R. G. EGGERT,[3] M. J. BRINEGAR,[4] and C. R. ANDERSON

University of Nebraska[5]

THERE has been interest by the producers of hybrid seed corn in the development of strains of corn which will yield higher percentages of protein. Such corn could be of much benefit in helping to meet the shortage of protein supplements. There are indications that corn high in protein contains a higher percentage of the protein as zein (Showalter and Carr, 1922), and since zein is very deficient in lysine and tryptophane (Osborne and Mendel, 1914a, b), it appears that the protein of high protein corn may not have as high a biological value as the protein of normal corn for swine. Dobbins *et al.* (1950) have demonstrated that the protein of high protein corn was of a lower biological value than that of normal corn for growing swine. The objectives of this study were to determine if greater deficiencies of lysine and tryptophane caused the lower biological value of the protein of high protein corn, and if so, what practical application could be made of these findings in feeding swine.

Experimental Procedure

Weanling barrow pigs were used in all experiments. They were weaned at approximately 8 weeks of age and were kept on a standard ration for at least a week prior to being placed on experiment. They were all allotted as evenly as possible into groups of four pigs each according to size and genetic background.

The pigs were fed individually. Daily feed intakes were equalized weekly at approximately 4.5 to 5 percent of body weight per day.

[1] Published with the approval of the Director as paper No. 590, Journal Series, Nebraska Agricultural Experiment Station. A part of the thesis presented to the Graduate College of the University of Nebraska in partial fulfillment of the requirements for the degree of Master of Science in Animal Husbandry.

[2] Acknowledgment is made of the provision of a grant-in-aid by Swift and Company, Chicago, Illinois, for partial support of this research. Samples of high protein corn of yellow dent varieties supplied by Tekseed Hybrid Corn Co., Tekamah, Nebraska, through courtesy of Mr. Vic Rediger. DL-tryptophane was supplied by Dow Chemical Company, Midland, Michigan. DL-lysine HCl was furnished by E. I. duPont de Nemours and Company, New Brunswick, New Jersey. Crystalline B-vitamins were generously supplied by Merck and Company, Rahway, New Jersey, and by Lederle Laboratories Division, American Cyanamid Company, Pearl River, New York.

[3] Present address: Laboratory of Animal Nutrition, Cornell University, Ithaca, New York.

[4] Present address: Allied Mills, Inc., Research Division, Box 459, Libertyville, Illinois.

[5] Departments of Animal Husbandry and Agricultural Chemistry, Lincoln 3, Nebraska.

Nitrogen balance data were obtained, using 7- or 8-day preliminary feeding periods followed by 5- or 6-day collection periods.

In phase 1, all experiments were of a single reversal design. Two diets were compared in each trial. Each diet was fed to two of the pigs during one period. The diets were then reversed during a second period. In phase 2, four diets were compared using two trials consisting of 4 x 4 Latin squares.

Results and Discussion

Phase 1—Studies with Corn as the Only Natural Protein Source

Experiment 1. The two samples of corn which were tested contained 10.1 and 11.4 percent of protein (dry matter basis). The protein contents of the diets were equalized at approximately 8 percent by the addition of corn starch. Minerals [6] and vitamins [7] were added to both diets.

The average nitrogen retention values, presented in table 1, show that for the normal corn diet the average apparently digested nitrogen retained was 31.8 percent while for the high protein corn diet it was 30.1 percent. Daily gains and feed efficiency values were also very similar. This would indicate that there was very little, if any, real difference in the quality of the protein of the two samples of corn.

Experiment 2. The two samples of corn used in the second experiment showed greater differences in protein content than those used in experiment 1. The normal corn contained 10.6 percent of protein, while the high protein corn contained 14.9 percent of protein. Again the diets were equalized to approximately 8 percent of protein by the addition of corn starch. Ruffex [8] and corn oil were added to the high protein corn diet to equalize the levels of fiber and fat. Vitamins and minerals were added as in experiment 1.

The average nitrogen retention values, presented in table 1, show that the percentage of apparently digested nitrogen retained from the normal corn diet was 37.2 percent as compared with 27.9 percent for the high protein corn diet. Statistical analysis of the results as paired data indicates that this difference is significant at the 5 percent level.

[6] Six pounds of mineral mixture per 100 lb. of diet. Contained monocalcium phosphate, 35 lb.; ground limestone, 20 lb.; NaCl, 20 lb.; KCl, 10 lb.; $MgCO_3$, 8 lb.; ferric citrate, 6 lb.; $MnSO_4$, 0.5 lb.; $CuSO_4$, 0.2 lb.; ZnO, 0.1 lb.; KI, 0.1 lb.; $CoCO_3$, 0.1 lb.; per 100 lb. of mineral mixture

[7] Contained thiamine, 50 mg; riboflavin, 200 mg.; Ca pantothenate, 700 mg.; pyridoxine, 100 mg.; niacin, 1500 mg.; Parvo (folic acid concentrate), 3.3 gm.; p-amino benzoic acid, 500 mg.; biotin, 25 mg.; inositol, 9.0 gm.; 2-methyl naphthoquinone, 450 mg.; viosterol, 25 mg. (9000 I.U.); vitamin A, 100,000 I.U.; mixed tocopherols, 4.5 gm.; vitamin B_{12}, 1 mg.; choline chloride, 45 gm.; per 100 lb. of diet.

[8] A commercial rice hull preparation by the Fischer Scientific Co.

TABLE 1. AVERAGE DATA FROM PHASE 1

Item	Experiment 1		Experiment 2		Experiment 3 [1]	
	Normal Corn 10.1% Protein [2]	H. P. Corn 11.4% Protein [2]	Normal Corn 10.6% Protein [2]	H. P. Corn 14.9% Protein [2]	Normal Corn Plus Lysine and Tryptophane	H. P. Corn Plus Lysine and Tryptophane
Number of pigs	4	4	4	4	4	4
Initial weight (lb.)	56.0	55.7	63.2	63.9	52.4	52.1
Daily feed intake (% of body weight)	4.79	4.78	4.18	4.28	4.20	4.20
Daily gain (lb.)	0.62	0.64	0.62	0.80	0.72	0.76
Daily gain (% of initial weight)	1.09	1.14	1.10	1.25	1.38	1.46
Pounds gained per pound of feed	0.211	0.220	0.239	0.266	0.300	0.315
Apparent digestibility of nitrogen (%)	72.5	74.0	69.3	73.5	72.4	76.0
Apparently digested nitrogen retained (%)	31.8	30.1	37.2	27.9	49.8	48.1

[1] The same samples of corn were used in this experiment as in experiment 2.
[2] All protein contents are on the basis of dry matter.

Although the nitrogen retention values for the normal corn diet were considerably higher than those for the high protein corn diet, the average daily gains for the two diets were reversed. The average gain was 0.80 pound per day for the high protein corn diet, as compared with 0.62 pound per day for the normal corn diet. This difference was not statistically significant. Since the diet containing high protein corn also contained considerable corn starch, and since the feed intake of the pigs consuming this diet was somewhat higher, it is possible that the greater gains were due to higher intakes of digestible energy.

Experiment 3. It was considered that the difference in nitrogen retention was possibly due to a difference in the amino acid composition of the protein of the two samples of corn tested in experiment 2. Showalter and Carr (1922) reported that higher protein corn contained a considerably larger part of the protein as zein than normal corn. Other workers (Hansen *et al.*, 1946; Frey, 1949; Frey *et al.*, 1949) have confirmed this finding. Since zein protein is very low in both lysine and tryptophane (Osborne and Mendel, 1914a, b; Block and Mitchell, 1946–47), it appears quite probable that the protein of the high protein corn may have been more deficient in these amino acids for swine than the normal protein corn. If so, the addition of sufficient lysine and tryptophane to both the high and normal protein corn diets used in experiment 2 should largely eliminate the difference between the two diets, provided there were no important differences in the amounts of other essential amino acids. Experiment 3 was designed to investigate this postulate.

The L-lysine requirement of growing pigs appears to be 0.6 percent of a diet containing approximately 10 percent of protein or 5.7 percent of the protein (Brinegar *et al.*, 1950). The tryptophane requirement appears to be about 0.2 percent of the diet as DL-tryptophane (Shelton *et al.*, 1951). With these values as guides, 1.75 percent of DL-lysine monohydrochloride and 0.3 percent of DL-tryptophane were added to the diets used in experiment 2. It was calculated that these levels would furnish ample lysine and tryptophane in each of the diets at the level of protein being fed.

Average nitrogen retention values, presented in table 1, show that the apparently digested nitrogen retained was 49.8 percent for the normal corn diet, as compared with 48.1 percent for the high protein corn diet. As was expected, more nitrogen was retained than in experiment 2 because of the additions of lysine and tryptophane. The results indicate that the differences between the two samples of corn as observed in experiment 2 were largely eliminated by the addition

of small excesses of lysine and tryptophane. Thus, it appears that the protein of the sample of high protein corn was more deficient in either lysine or tryptophane, or both, than was the protein of normal corn. Realizing that there possibly are other limiting essential amino acids in the protein of normal corn, it appears that the protein of the high protein corn was no more deficient in these other amino acids than was the protein of normal corn when all of the protein in the diet was supplied by corn alone plus added lysine and tryptophane.

Phase 2—Studies Using Natural Protein Supplements

This experiment was designed to determine whether the greater deficiency of lysine and/or tryptophane in high protein corn shown in the previous experiments is of any practical significance when the corn is supplemented with practical protein supplements to give diets containing approximately 17 percent of protein. The problem of effectively utilizing the high protein corn appeared to be one of correcting the greater lysine and/or tryptophane deficiency while using less protein supplement to obtain the desired level of protein in the diet.

Two types of protein supplements were used. From average amino acid values compiled from the literature (Block and Mitchell, 1946–47; Baumgarten, Mather and Stone, 1946; Lyman *et al.,* 1947; Lyman and Kuiken, 1949; Williams, 1950), it was considered that few of the commonly used protein supplements are as deficient in tryptophane as in lysine for supplementing corn protein. Supplement A was designed to contain a high level of lysine and to be adequate in tryptophane. This supplement consisted of 50 percent of soybean meal (41 percent protein, expeller), 25 percent of blood flour and 25 percent of fish meal. Supplement B was designed to be adequate in tryptophane but to contain no more lysine than is present in most supplements in common use. Soybean meal was used as the major source of protein. In order to more nearly equalize the levels of protein in the two supplements, 51 percent protein solvent type soybean meal was used in Supplement B.

Two samples of high protein corn were available for use in this experiment. One contained 13.9 and the other 12.4 percent of protein. Each of these was compared in separate trials with a sample of corn containing 9.1 percent of protein. In each trial, the two supplements were tested with each of the two samples of corn (high and low protein). All diets contained in aureomycin-vitamin B_{12} supplement.

Average performance values for each trial are shown in table 2.

TABLE 2. AVERAGE DATA FROM PHASE 2

	Trial 1				Trial 2			
	Normal Corn (9.1% protein)[1]		High Protein Corn (13.9% protein)		Normal Corn (9.1% protein)[1]		High Protein Corn (12.4% protein)	
	Supplement A[2]	Supplement B[2]	Supplement A[2]	Supplement B[2]	Supplement A[2]	Supplement B[2]	Supplement A[2]	Supplement B[2]
Number of pigs	4	4	4	4	4	4	4	4
Initial weight (lb.)	76.0	76.1	76.8	77.2	57.6	59.7	61.6	63.2
Daily feed intake (% of body weight)	4.15	4.20	4.24	4.21	4.14	4.14	4.19	4.20
Daily gain (lb.)	1.48	1.43	1.31	1.20	1.17	1.22	1.16	1.17
Daily gain (% of initial weight)	2.00	1.89	1.69	1.54	2.09	2.02	1.89	1.79
Pounds gained per pound of feed	0.421	0.398	0.358	0.329	0.438	0.424	0.398	0.378
Apparent digestibility of nitrogen (%)	82.2	79.6	78.5	77.6[3]	81.5	82.0	80.2	82.0
Apparently digested nitrogen retained (%)	52.7	49.1	42.5	47.1[3]	56.7	54.7	48.4	47.0

[1] These diets contained the same sample of corn.

[2] Supplement A contained soybean oil meal (41% protein, expeller), 50%; fish meal, 25%; blood flour, 25%. Supplement B contained soybean oil meal (51% protein, solvent). All diets contained alfalfa meal, 5%; dried whey, 1%; condensed fish solubles, 1%; steamed bonemeal; limestone; salt; riboflavin; niacin; calcium pantothenate; and 0.25% Aurofac (Lederle's aureomycin-vitamin B_{12} supplement); in addition. Protein supplements were added at a rate such that each mixed diet contained approximately 17% protein.

[3] Average of 3 values. One pig became crippled during collection period and missed the collection.

It is readily apparent that greater nitrogen retention resulted from feeding the normal protein corn than from either of the samples of high protein corn. According to analyses of variance of the nitrogen retention values for each trial, the variance due to difference in diets was significant at the 1 percent level. Slightly over one-half of the variance due to diets in trial 1 proved to be due to a corn by supplement interaction ($P<.01$). Most of the remainder was due to a difference between the normal and high protein corn ($P<.02$). There was no significant difference between protein supplements in trial 1. Practically all of the variance between diets in trial 2 was due to differences between normal and high protein corn ($P<.01$). No appreciable amount of variance was due to differences between supplements or to a supplement by corn interaction.

Since biological values have been shown to decrease as pigs increase in body weight (Bell and Loosli, 1951), analyses of covariance were computed in an attempt to allow for the collective errors introduced by advancing age and weight of the pigs. These covariance analyses did not remove any appreciable amount of variation in the data.

The daily gains (as percent of initial weight) of both trials were subjected to an analysis of variance after transforming the percentage values to corresponding angles by arc sin tables (Snedecor, 1946). The difference in daily gains due to diets was significant at the 5 percent level. Variance due to differences between normal and high protein corn diets accounted for practically all of the diet sums of squares. Variance due to difference between supplements, and that due to a corn by supplement interaction, was negligible. The daily gains appear to be only suggestively in favor of supplement A.

The data appear quite conclusive in demonstrating that the proteins of both samples of high protein corn were not supplemented as effectively with either of the protein supplements tested as was the protein of the normal corn. Even though the studies reported in phase 1 indicate that added lysine and/or tryptophane eliminates the difference between some samples of high and normal protein corn, the inclusion of proteins high in lysine (blood flour and fish meal), in favor of soybean meal alone as a supplement to corn, did not eliminate the difference in growth and nitrogen retention between pigs fed the samples of high and normal protein corn tested in this phase of the studies. If the estimated requirement for tryptophane and the calculated levels of tryptophane present in the diets, as reviewed earlier, are correct, it would seem that the level of tryptophane was not a limiting factor in the later studies. It appears that the level

of lysine in the supplements was too low for effective supplementation of the high protein corn. However, none of these estimations can be applied to these studies with certainty. Also, possibly the lysine and tryptophane of the protein supplements may not have been entirely available for use by the pig. Likewise, it is probable that the addition of the supplements changed the relative amounts of amino acids in the diets, and it is possible that the samples of corn used in the second trial contained different levels of amino acids than those used in the first trial. Such factors could explain the unexpected differences between the two trials in phase 2.

Summary

The quality of the protein of several samples of normal and high protein corn for growing swine was compared using nitrogen balance techniques. The value of the protein of samples of corn containing 10.1 and 11.4 percent of protein was found to be approximately the same. When samples of corn containing 10.6 and 14.9 percent of protein were compared, the percentage of the apparently digested nitrogen retained from the 10.6 percent protein corn was significantly greater than for the high protein (14.9 percent) corn. The addition of calculated excesses of lysine and tryptophane to both diets largely eliminated the previously demonstrated differences in percent of apparently digested nitrogen retained.

Data obtained from studying two samples of high protein corn (13.9 and 12.4 percent of protein) compared separately with those obtained with a sample of normal corn (9.1 percent of protein), each being supplemented with two different protein supplements to give diets containing approximately 17 percent of protein, indicated that: (1) greater nitrogen retention and daily gains were obtained when normal protein corn was fed than when high protein corn was used in the diet, and (2) the difference between the two protein supplements used was not significant.

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PORK CARCASS VALUE AS AFFECTED BY PROTEIN LEVEL AND SUPPLEMENTATION WITH AUREOMYCIN AND VITAMIN B_{12}[1]

G. D. Wilson, J. E. Burnside, R. W. Bray, P. H. Phillips and R. H. Grummer

University of Wisconsin[2]

In recent years considerable emphasis has been placed on the production of hogs which will yield a higher percentage of their weight in lean cuts. Within the last 3 years, the growth-stimulating effects of vitamin B_{12} and various antibiotics in swine rations have been established and it is now desirable to know if the accelerated gains significantly influence the lean-fat ratio in the carcasses. The effects of level of protein on hog carcasses have been investigated by the U.S.D.A. (1941). A summary of 2 years' work showed that the carcasses of hogs fed to slaughter weight on rations averaging 18 percent protein produced more lean tissue and less fatty tissue than hogs receiving 13 percent protein. Investigations by Cunha *et al.* (1950), Catron *et al.* (1952), and others have suggested that antibiotics have a "protein sparing effect" in swine rations.

More recently Catron *et al.* (1952) found no significant difference in the percentage of lean in carcasses from hogs fed rations that differed as much as 6 percent in level of protein. These workers further found that dressing percentage, body length, body depth, or depth of fat back were not affected by the addition of 10 mg. of aureomycin and 10 mcg. of vitamin B_{12} per pound of ration. Vohs *et al.* (1951) reported no significant differences in depth of fat back of carcasses when 15 mcg. of vitamin B_{12} per pound of ration or 0.66 percent APF (equivalent to 15 mcg. of B_{12} and 10.5 mg. of aureomycin per pound of ration) was added to a ration averaging 15 percent protein. Bowland *et al.* (1951) tested the effects of an APF supplement on carcasses from Yorkshire pigs fed a small grains ration. Their results indicate that rations containing 0.5 percent APF (supplying residual aureomycin in addition to 12.5 mcg. of vitamin B_{12} per pound) reduced carcass length and increased fat deposition resulting in lower carcass values. These differences, however, were not statistically significant at the 5 percent probability level.

[1] Published with the approval of the director of the Wisconsin Experiment Station, Madison. This work supported in part by Oscar Mayer & Co., Inc.

[2] Departments of Animal Husbandry and Biochemistry, Madison, Wisconsin.

The present study was conducted to determine the effect on the carcass value of supplementing a growing-fattening ration with crystalline aureomycin and vitamin B_{12} within each of three protein levels.

Experimental

Ninety-six feeder pigs, averaging 45 pounds, were randomly distributed into 12 lots of eight pigs each. All lots were fed a corn, soybean oil meal, alfalfa meal ration. High, intermediate, and low levels of protein were fed to each of three groups of four lots each. The initial protein levels for the three groups were 20, 17, and 14 percent. When the average weight of the pigs in each lot reached 75 pounds, the protein percentages were lowered to 16, 13, and 11 percent, respectively. From 150 to 210 pounds the protein was further reduced to 12, 10, and 9.5 percent. The four lots within each protein level were fed as follows: lot 1, control ration; lot 2, control plus 20 mcg. of crystalline vitamin B_{12} per kilogram of air-dry ration; lot 3, control plus 20 mg. of aureomycin per kilogram of ration; lot 4, control plus aureomycin and vitamin B_{12} in combination at the levels fed in lots 2 and 3.

When the average weight of a lot reached 213 pounds, the pigs were slaughtered packer style, and after a 24- to 48-hour chill the right side was measured and cut. The area of the butt end of the ham and of the longissimus dorsi muscle of the loin was determined from tracings with a compensating plainimeter.

The coefficients of variation for the slaughter weight of the animals on high, intermediate, and low protein levels were 8.4, 14.9, and 30.0 percent, respectively. Because of this variation the analysis of covariance as outlined by Snedecor (1946) was used in the statistical treatment of the data.

The adjusted mean values for the carcass characteristics studied are presented in table 1. In the analysis, each treatment was compared to the control within its respective protein level. Comparisons were also made to determine if the best treatments of the lower levels of protein were significantly different from the high protein control lot. The between-protein analysis permitted the over-all comparison of the adjusted mean values of the medium and low protein groups with those of the high protein group.

Results and Discussion

Of particular interest in table 1 is the percentage of lean cuts in the carcasses. Pigs receiving high protein rations produced leaner

TABLE 1. SUMMARY OF CARCASS ANALYSIS

Protein Level	Lot No.	Daily Gain	Slaughter Weight	Dressing Percentage	Primal Cuts	Lean Cuts	Skinned Ham	Trimmed Loin	Boston Butt	Picnic Shoulder	Belly	Fat Back Depth	Carcass Length
		lb.	lb.	%	%	%	%	%	%	%	%	cm.	cm.
High protein	1	1.62	213.6	70.2	63.9	49.6	17.4	15.0	7.4	9.8	14.3	4.34	73.7
	2	1.59	213.9	69.1	63.6	50.3	17.9	15.1	7.7	9.7	13.4	4.42	73.7
	3	1.60	213.1	69.8	64.0	50.2	17.1	15.2	7.7	10.3	13.8	4.47	72.6
	4	1.75	212.2	72.4	62.2	46.7*	16.3**	14.0	6.8	9.5	15.5	4.93	73.9
Medium protein	1	1.43	213.4	72.2	61.5	45.3	16.2	12.6	6.9	9.7	16.2	4.72	73.2
	2	1.43	212.1	72.8	62.5	47.8*	16.9	14.2**	7.1	9.6	14.7*	4.78	72.1
	3	1.78**	210.4	72.2	63.6	47.5	16.3	14.2**	7.3	9.5	16.0	4.78	71.9
	4	1.67	210.5	74.1	65.1*	49.6**	17.2*	14.0**	7.5	10.6**	15.5	4.70	72.4
Low protein	1	0.96	213.2	72.6	58.9	43.7	15.7	12.2	5.7	10.0	15.2	4.72	72.6
	2	1.09	215.2	72.6	62.0**	46.4*	15.7	13.2	6.8*	10.9**	15.6	4.47	73.4
	3	1.20	212.8	71.7	62.1**	47.3**	16.3	13.4**	6.6	11.1**	14.8	4.80	73.7
	4	1.32**	213.2	72.0	62.7**	47.5**	16.1	13.6*	6.5	11.2**	15.3	4.57	73.7
L.S.D. t.05		0.26	N.S.	N.S.	2.30	2.21	0.94	1.01	0.90	0.64	1.41	N.S.	N.S.
L.S.D. t.01		0.35	N.S.	N.S.	3.05	2.93	1.25	1.34	1.20	0.85	1.87	N.S.	N.S.
Protein													
High				70.3	63.4	49.2	17.2	14.9	7.4	9.8	14.2	4.55	73.4
Medium				72.9**	63.2	47.6**	16.6**	13.7**	7.2	10.0	15.6**	4.75	72.4*
Low				72.2**	61.4**	46.2**	15.9**	13.1**	6.4	10.7**	15.2**	4.65	73.4
L.S.D. t.05				1.10	1.26	1.32	0.50	0.55	N.S.	0.37	0.73	N.S.	0.81
L.S.D. t.01				1.45	1.66	1.74	0.67	0.73	N.S.	0.50	0.96	N.S.	1.07

* Significant at 5% level.
** Significant at 1% level.
N.S.=Not significant.

carcasses than those on medium or low protein. Within the high protein group the addition of aureomycin and vitamin B_{12}, alone or in combination, did not significantly increase the proportion of lean cuts; in fact, the combination treatment significantly lowered the percentage of lean cuts from that produced by the high protein basal. Within the medium protein group there was a significant increase in the lean cuts percentage when vitamin B_{12} alone or in combination with aureomycin was fed. The difference between the control and the aureomycin treated lots within the medium protein group approached significance. All treatments in the low protein group increased the lean-fat ratio in the carcass. Pigs receiving the intermediate levels of protein plus B_{12} and aureomycin produced carcasses with as large a proportion of their weight in lean cuts as those on the high protein basal ration. The combination of vitamin B_{12} and aureomycin gave the greatest increase in lean cuts within the low protein lots. However, this yield was 2.1 percent lower than that in the high protein control lot, a difference which approached significance. The percentage of primal cuts within the low protein group was increased by all treatments. This difference in primal cuts appeared only in the low protein lots. When the five wholesale cuts were analyzed individually, the treatment effects noted for the percentage of lean and primal cuts were reflected more in the loin and picnic shoulder than in the other three cuts.

The differences due to protein level are in general agreement with those published by the U.S.D.A. (1941) but oppose the findings of Catron *et al.* (1952). The latter authors, using the percent lean in the cross section of the last rib as a criterion of leanness, found no difference due to the percent of protein in the ration and they suggested that perhaps a leaner type of hog would have brought out the effect noted by the U.S.D.A. workers. Referring to table 1, it can be seen that the mean fat back thickness for the pigs in this experiment was 4.65 cm. or 1.83 inches which is the average reported by Catron *et al.*

The fat back thickness of the carcasses showed no significant difference due to treatment within or between protein levels in the ration. This is somewhat unusual since the correlation between fat back thickness and percentage of lean cuts was —0.77. It is thought that the variation in slaughter weights and hence the fat back thickness of the pigs within lots was responsible for the high L.S.D. required for significance.

Neither dressing percentage nor length of carcass were affected by

any treatment within a protein level. However, between protein levels the dressing percentage of the high protein lots was significantly lower than that of the medium and low protein lots.

The results of this experiment, in regard to fat back thickness and length of carcass, are in agreement with the findings by Vohs *et al.* (1951) and Catron *et al.* (1952), but in part contrary to those of Bowland *et al.* (1951). In regard to the leanness of the carcasses Bowland *et al.* (1951) reported an increase in fatness when a 15 percent protein ration was supplemented with aureomycin and B_{12}. Such an effect was shown in this experiment only when the high protein ration was used and there was no stimulation of gain. The reason for this discrepancy within comparable protein levels is not clear. They have attributed the increased fatness to the very fast gains during the finishing period. The analyses of growth data for this experiment show that the magnitude of the increased gains due to the addition of aureomycin and B_{12} was no greater in the finishing period than in the initial feeding period.

Summary and Conclusions

Carcass data from 96 pigs, receiving three levels of protein, and supplements of aureomycin and vitamin B_{12} within the protein levels, have been presented.

On a ration averaging 18 percent protein, the addition of 20 mcg. of vitamin B_{12} and 20 mg. of aureomycin, alone or in combination, did not significantly increase the percentage of lean cuts, dressing percentage, fat back depth, or length of carcass. Within the medium protein lots an increase in the leanness of the carcasses resulted from all treatments, the combination of aureomycin and B_{12} resulting in as high a percentage of lean cuts as the high protein basal ration. Supplementation of the low protein ration resulted in an increase in the percentage of lean cuts in each of the three lots, the increase being somewhat greater than in the medium protein groups with similar supplements. Fat deposition was not increased when the addition of vitamin B_{12} and aureomycin accelerated gains.

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EFFECT OF AUREOMYCIN AND VITAMINS ON GROWTH AND BLOOD CONSTITUENTS OF PIGS FED CORN AND BANANA RATIONS [1]

ROBERT L. SQUIBB, EUGENIO SALAZAR, MIGUEL GUZMÁN, and NEVIN S. SCRIMSHAW [2, 3]

Instituto Agropecuario Nacional and Instituto de Nutrición de Centro-América y Panamá

CORN is expensive in Guatemala and is used there principally as a food for human beings. Animal-protein feedstuffs are unavailable. For these reasons, workers in nutrition in that country have stressed the importance of finding local substitutes for corn and evaluating antibiotics in combination with local vegetable proteins. Squibb and Salazar (1951) demonstrated that ripe bananas, including the skins, could replace some of the carbohydrates of corn in rations for growing and fattening pigs. They found also that addition of an APF (Animal Protein Factor) concentrate to the rations increased the rate of gain and the efficiency of feed utilization.

The object of the studies reported here was, first, to determine whether ripe bananas, including the skins, could replace *all* of the carbohydrates supplied by corn in rations for growing and fattening pigs and, second, to determine the effect of crystalline aureomycin and a vitamin concentrate on the growth of pigs and on several constituents of their blood.

Procedure

Sixty Duroc-Jersey pigs, all of which had been on pasture, were used in the two experiments reported here. They were assigned to experimental groups on the basis of age and weight, and each group of pigs was housed in a pen with a solid concrete floor and walls. Pens were washed thoroughly each day. Fresh water and the test

[1] A contribution from the Instituto Agropecuario Nacional in Guatemala, a technical agricultural organization for that country operated jointly by the Government of Guatemala and by the Office of Foreign Agricultural Relations, U. S. Department of Agriculture. United States participation in this work was carried out as part of the Point IV program, administered by the Technical Cooperation Administration, U. S. Department of State. The financial assistance of the Instituto de Fomento de la Producción of Guatemala is gratefully acknowledged.

[2] Dr. Squibb, from the Instituto Agropecuario Nacional; Messrs. Salazar and Guzmán and Dr. Scrimshaw, from the Instituto de Nutrición de Centro-América y Panamá, Guatemala, a human nutrition institute supported by the Governments of Central America and Panama and administered by the Pan American Sanitary Bureau, Regional Office of the World Health Organization.

[3] The authors acknowledge the valuable help of Dr. M. K. Wyld and Dr. Henry Hopp in the statistical analyses of the data, and of Francisco Aguirre in making the determinations of the red-cell count, hematocrit, and hemoglobin of the pigs' blood.

rations were provided *ad libitum*. In addition to the rations, each pig was fed 0.75 pound of fresh green Kikuyu grass *(Pennisetum clandestinum)* per day as a supplemental source of carotene and other essential nutrients. All feed refused was weighed back and was not charged to feed consumption. Each pig was weighed once a week.

TABLE 1. GROWTH AND FEED UTILIZATION OF PIGS FED CORN AND BANANA RATIONS, EXPERIMENT 1

Ration [1]	Average Weight		Average Daily Gain	Feed Efficiency [2]
	At Start of Experiment	At End of Experiment		
	lb.	lb.	lb.	lb. feed per 100-lb. gain
	8 pigs in each group, on rations 140 days			
Corn	39	163	0.88	393
Bananas	40	191	1.07	509
	9 pigs in each group, on rations 91 days			
Corn	65	170	1.15	380
Bananas	65	182	1.28	451

[1] Rations were as follows:

Corn:

For pigs weighing 30–124 lb.: sesame oil meal, 40; ground yellow corn, 57; bonemeal, 1; calcium carbonate, 1; and salt, 1. (Crude protein, 15 percent.)

For pigs weighing 125–200 lb.: sesame oil meal, 23; ground yellow corn, 74; bonemeal, 1; calcium carbonate, 1; and salt, 1. (Crude protein, 15 percent.)

Bananas:

For pigs weighing 30–124 lb.. 1 part of concentrates (sesame oil meal, 45; bonemeal, 1; calcium carbonate, 1; and salt, 1) to 4 parts of bananas. (Crude protein, 21 percent.)

For pigs weighing 125–200 lb.: 1 part of concentrates to 5 parts of bananas. (Crude protein, 15 percent.)

[2] Ripe bananas were reduced to the same moisture content as the corn.

Experiment 1

In Experiment 1, duplicate groups of pigs were fed rations containing either corn or ripe bananas as the principal source of carbohydrates. The bananas, which were overripe and included the skins, were fed to replace all the carbohydrates of corn and to supply the same amount of dry matter as corn. The number of pigs, length of trials, rations fed, and the pigs' growth and efficiency of feed utilization are presented in table 1.

Experiment 2

In Experiment 2, a comparison was made of the rates of growth of pigs fed corn and banana rations with and without the addition

of (1) a vitamin concentrate, or (2) crystalline aureomycin. The number of pigs used in this study, the length of the experiment, rations fed, and the growth and efficiency of feed utilization of the pigs are presented in table 2.

In this experiment the effect of the supplements on several constituents of the blood of the pigs was also observed. Approximately 5 ml. of blood was collected from the tail of each pig at the start

TABLE 2. GROWTH AND FEED UTILIZATION OF PIGS FED CORN AND BANANA RATIONS SUPPLEMENTED WITH A VITAMIN CONCENTRATE AND WITH AUREOMYCIN, EXPERIMENT 2

Ration	Number of Pigs	Number of Days	Average Weight		Average Daily Gain	Feed Efficiency [1]
			At Start of Experiment	At End of Experiment		
			lb.	lb.	lb.	lb. feed per 100-lb. gain
			Basal rations [2]			
Corn	10	49	46	76	0.64	352
Bananas	10	49	45	85	0.82**	362
			Rations supplemented with vitamin concentrate [3]			
Corn	10	49	47	80	0.67	355
Bananas	10	49	46	87	0.83**	358
			Rations supplemented with aureomycin [4]			
Corn	10	49	47	83	0.72	304
Bananas	10	49	46	91	0.92**	305

[1] The ripe bananas were reduced to the same moisture content as the corn.

[2] Basal corn rations (protein, 24 percent) consisted of the following: sesame oil meal, 40; ground yellow corn, 57; calcium carbonate, 1; bonemeal, 1; salt, 1; and Delsterol, 3 gm. per 100 lb. of ration. Basal banana rations (protein, 24 percent) consisted of the following: sesame oil meal, 94; calcium carbonate, 2; bonemeal, 2; salt, 2; bananas, 4 parts, by weight, to 1 part of concentrates; and Delsterol, 3 gm. per 100 lb. of ration.

[3] Vita-Rich, starter grower, fed to replace 1 percent of the corn in the basal corn rations, or 1 percent of the sesame oil meal in the basal banana rations. Claimed by manufacturer, Thompson-Hayward Chemical Co., to contain (in a carrier of sardine and whey solubles, fish liver, and glandular meals, etc.), per pound, not less than 300 mg. riboflavin, 250 mg. pantothenic acid, 10,000 mg. choline, 20 mg. thiamine, 300 mg. niacin, 0.5 mg. vitamin B_{12}, 90,800 AOAC chick units of vitamin D, and 90,800 U.S.P. units of vitamin A.

[4] Aureomycin HCl (crystalline), courtesy of Dr. T. H. Jukes, Lederle Laboratories.

** Difference between pigs fed bananas and pigs fed corn significant at the 1% level.

and end of the experiment. The serum from these samples was analyzed for serum proteins (method by Lowry and Hunter, 1945), riboflavin (method by Burch *et al.*, 1948), ascorbic acid (methods by Goodland *et al.*, 1949, and Lowry *et al.*, 1945, which were modified by using a solution of copper sulfate and thiourea instead of norite), carotenoids and vitamin A (method by Bessey *et al.*, 1946), tocopherols, and alkaline phosphate.

In addition, 2 ml. of blood was taken at the end of the experiment from each of five pigs selected at random from each group.

These samples were collected in tubes containing an anticoagulant. Red-cell count, hemoglobin content, and percent of hematocrit were determined on each of these samples by standard methods (Wintrobe, 1946). The blood data are presented in table 3.

Results and Discussion

Data in both tables 1 and 2 are evidence that ripe bananas may be fed to replace corn as a source of carbohydrates in rations for growing and fattening pigs. In Experiment 1, although no significant differences appeared between the rate of gain of pigs fed bananas and the rate of those fed corn, a statistical analysis of the data indicated that, during the period when the pigs weighed less than 90 pounds, the groups fed bananas showed a highly significant increase in the rate of gain over those fed corn. This observation was confirmed by Experiment 2. The reason for this increased growth of younger pigs fed bananas was not determined.

In Experiment 2, pigs fed banana rations, whether with or without vitamin or aureomycin supplements, gained significantly faster than those fed corn with or without these supplements. Addition of the vitamin concentrate did not improve the rate of gain with either the corn or banana rations (table 2). In both rations, however, addition of crystalline aureomycin increased, though not significantly, both the rate of gain and the efficiency of feed utilization.

Two principal types of changes in the levels of blood nutrients may be expected in pigs under the conditions of these experiments: (1) those that will occur irrespective of treatment, e.g., changing from pasture to dry lot; and (2) those that will occur because of treatment. When the blood data collected in Experiment 2 (table 3) were analyzed statistically, these two conditions were taken into consideration.

The data may be summarized as follows:

Serum proteins	Showed no consistent changes, irrespective of treatment.
Riboflavin	Decreased significantly in all groups except the ones fed diets to which the vitamin concentrate had been added; these groups showed some increase.
Ascorbic acid	Was reduced in all groups, with no apparent effect from the treatments.
Carotenoids	Increased in all groups, with significant increases being noted in the group fed corn, the groups fed corn or bananas with a vitamin supplement, and the group fed bananas with aureomycin.

TABLE 3. EFFECT OF VITAMIN CONCENTRATE AND AUREOMYCIN IN CORN AND BANANA RATIONS ON SEVERAL CONSTITUENTS OF THE BLOOD OF GROWING PIGS, EXPERIMENT 2

Ration	Serum Proteins		Ribo-flavin		Ascorbic Acid		Caro-tenoids		Vitamin A		Toco-pherols		Alkaline Phosphatase		Red-Cell Count, End	Hemo-globin, End	Hemato-crit, End
	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End			
	gm.%		γ%		gm.%		γ%		γ%		mg.%		mM/l/hr.[1]		thou-sands/c.c.	gm.%	%
Basal rations																	
Corn	6.83	6.56	3.27	1.97	1.92	1.72	3.4	11.3	26.4	26.8	0.26	0.47	1.78	3.83	6648	11.5	38.0
Bananas	6.74	6.98	2.50	1.84	2.17	1.58	7.2	7.5	24.3	28.9	0.09	0.46	2.22	3.27	6248	10.8	36.6
Rations supplemented with vitamin concentrate [2]																	
Corn	6.71	6.59	2.85	3.01	2.35	1.64	8.8	12.4	27.1	31.0	0.11	0.53	1.94	2.63	7166	11.5	39.4
Bananas	6.56	6.87	2.86	3.13	2.12	2.02	6.8	11.1	25.9	29.1	0.22	0.57	1.67	2.74	6120	11.1	37.4
Rations supplemented with aureomycin [3]																	
Corn	6.96	6.57	2.67	1.78	1.92	1.79	10.0	12.6	24.9	30.7	0.11	0.46	2.14	2.47	6876	11.1	37.6
Bananas	7.04	7.14	2.60	1.44	1.77	1.72	9.0	16.7	22.7	39.2	0.07	0.66	2.58	2.10	6222	10.9	36.4
Pooled standard error of the mean (+ or −)	0.28		0.57		0.38		3.6		7.0		0.11		0.79		478	0.64	2.00
Difference due to—																	
Bananas	0.42**		0.12		0.06		−0.3		2.9		0.08**		0.27		700**	−0.43	−1.53*
Vitamins	−0.04		1.16**		0.18		2.4*		2.2		0.08*		−0.86**		195	0.2	1.1
Bananas × vitamins	−0.07		0.12		0.26**		1.2		−2.0		0.02		−0.16		−323	0.2	−0.3
Aureomycin	0.08		−0.29		0.10		5.2**		7.1**		0.10**		−1.26**		101	−0.2	−0.3
Bananas × aureomycin	0.07		−0.10		0.04		4.0**		3.2		0.10**		0.10		−127	0.2	0.1

[1] Millimoles per liter per hour.
[2] See table 2, footnote 4, for composition of vitamin concentrate.
[3] Aureomycin HCl (crystalline), courtesy of Dr. T. H. Jukes and the Lederle Laboratories.
* Significant at the 5% level.
** Significant at the 1% level.

Vitamin A	Increased in all groups, significantly so in the group fed bananas and aureomycin.
Tocopherols	Increased significantly in all groups irrespective of treatment.
Alkaline phosphatase	Increased significantly in the groups fed the corn and banana rations, whether with or without the vitamin supplement; showed no increase in the groups fed aureomycin.
Red-cell count, hemoglobin, hematocrit	Showed no significant differences among the various groups except that those fed bananas, with or without the vitamin or aureomycin supplements, had a lower red-cell count and a lower percent of hematocrit than the groups fed corn.

Data are not sufficient to explain all the changes that occurred in the various constituents of the pigs' blood in this experiment. In the groups fed corn or bananas plus the vitamin supplement, the increase of serum riboflavin, carotenoids, tocopherols, and vitamin A may be attributed to this concentrate's increasing the quantity of these vitamins in the rations. In the groups fed bananas and aureomycin, the increase of carotenoids (vitamin A activity) and vitamin A was significant. Since similar increases did not occur in the pigs fed corn and aureomycin, it is probable that aureomycin was not directly responsible for the increase.

There are indications that aureomycin may be related to a slow increase in alkaline phosphatase (in the corn group) or an actual decrease (in the banana group). Further, there were lower red-cell counts and hematocrit values in the blood of pigs fed bananas. No explanation can be given for these phenomena.

The fact that aureomycin showed no clear-cut effects on the blood constituents of young growing pigs is in agreement with the findings for hens (Squibb *et al.*, 1951) and for human beings (according to some data collected by Scrimshaw in 1951). Whatever metabolic activity aureomycin may possess, it apparently does not influence these constituents—a conclusion that will have to be revised if the depressing effect it had on the alkaline phosphatase levels of the pigs proves constant.

Summary

The studies reported here indicated that ripe bananas, fed with their skins, satisfactorily replace corn in rations for growing and fattening

pigs, but that they are more effective during the period when the pigs weighed less than 90 pounds than for heavier, older pigs.

Aureomycin increased, though not significantly, the growth of pigs fed either corn or banana rations, and also the efficiency of their feed utilization.

Aureomycin did not have any apparent effect on serum proteins, riboflavin, ascorbic acid, carotenoids, vitamin A, tocopherols, red-cell count, hemoglobin, and hematocrit in the blood of young growing pigs.

The increase in alkaline phosphatase values observed in pigs fed either corn or bananas seemed to be depressed by the addition of aureomycin to the pigs' diet.

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GROWTH EFFECTS OF SOME ANTIBIOTICS ON SUCKLING, GROWING, AND FATTENING PIGS

W. P. Lehrer, Jr., E. R. Pharris, W. R. Harvey and T. B. Keith

University of Idaho Agricultural Experiment Station [1]

STUDIES on the addition of various antibiotics to swine rations have been reported by a number of research workers during the past few years. Many of these workers have shown that antibiotics added to swine rations have a growth-stimulating effect. Among the workers whose results showed increased growth rate in pigs when antibiotics were added to swine rations are: Brown and Luther (1950), Carpenter (1950), Cunha *et al.* (1950), Edwards *et al.* (1950), Jukes *et al.* (1950), and Luecke *et al.* (1950, 1951). Cuff *et al.* (1950) have reported that the feeding of antibiotics to "runt" pigs significantly increased daily gains and reduced scouring.

The work reported in this paper is concerned with the effect of feeding crystalline aureomycin and crystalline terramycin to suckling, growing, and fattening pigs. The pigs were started on the antibiotics at either 2 days of age or 4 weeks of age. Antibiotic supplementation was stopped at either 4 weeks, weaning age (8 weeks), or market weight (200 pounds).

Experimental Procedure

The pigs used in these studies were purebred Durocs and Poland Chinas from sows that had been fed well-balanced rations and managed under normal, accepted farm conditions at all times. The basal rations fed during the course of these trials are presented in table 1.

The studies were conducted in two phases. In the first phase 18 litters of Durocs and Poland Chinas were used. In this study entire litters received a supplement of either crystalline aureomycin or crystalline terramycin at various stages of pig growth. A total of 141 pigs was used in this trial. Table 2 shows when antibiotic supplementations were fed. Pigs supplemented with antibiotics during the first 4 weeks of the suckling period received 2.5 mg. per day via capsule (2.5 mg. antibiotic plus 97.5 mg. cornstarch). Those receiving

[1] Published with the approval of the Director of the Idaho Agricultural Experiment Station, Moscow, Idaho, as Research Paper No. 360.

antibiotics during the last 4 weeks of the suckling period were fed 5 mg. of the antibiotic per pound of feed in the creep ration. Animals fed antibiotics after weaning received 7.5 mg. per pound of feed.

The second phase of the study was designed to determine the effect of antibiotic supplementation within litters. This was accomplished by splitting each of six litters, with an adjusted total of 36 pigs, into three groups. One group was used as a control, a second group was given 2.5 mg. of crystalline aureomycin via capsule, and the third group was given 2.5 mg. of crystalline terramycin via capsule. The

TABLE 1. RATIONS [1, 2]

Feed Stuff	Creep	Weaning to 75 lb.	75 lb. to 125 lb.	125 lb. to 200 lb.
Barley (rolled)	30	..	..	..
Barley (ground)	..	30	40	55
Oats (rolled)	30	..	..	..
Oats (ground)	..	18	18	18
Wheat (ground)	25	..	..	..
Wheat shorts	..	10	10	10
Wheat bran	..	10	10	10
Alfalfa meal, dehydrated	5	5	5	..
Linseed oil meal	..	2	2	2
Alaska peas (ground)	..	20	10	..
Meat meal	5	2	2	2
Fish meal (herring)	5	2	2	2
Salt (iodized)	0.5	0.5	0.5	0.5
Steamed bone meal	0.5	0.5	0.5	0.5

[1] Alfalfa pasture was available at all times.
[2] Rations were fed via self-feeders.

pigs in each group were marked for easy identification and remained with their respective dams throughout the suckling period. During the first 4 weeks of the suckling period, each antibiotic-supplemented pig received one 100 mg. capsule (2.5 mg. antibiotic and 97.5 mg. cornstarch) of the antibiotic mixture daily. Pigs in this series were fed no antibiotics after they became 4 weeks old (table 3).

Animals in both series were moved to alfalfa pasture with their dams and permitted access to creeps when the pigs were about 4 weeks of age. At weaning (8 weeks), dams were removed from the pasture lots and the pigs fed via self-feeders for the remainder of the growing-fattening period. The pigs in both series were individually weighed at weekly intervals during the suckling period and twice a month thereafter.

Results

Means of the average daily gains made by the 141 pigs in the first experiment to 8 weeks of age, 100 pounds of weight, and to 200 pounds of weight are given in table 2. Since the Durocs gained faster in almost all groups than the Poland Chinas, and since the breeds were unequally represented in the different groups, the gains are given separately for the two breeds. The number of pigs in each breed that started the experiment is given for each group separately in the first

TABLE 2. MEANS AND STANDARD ERRORS OF AVERAGE DAILY GAINS BY ANTIBIOTIC SUPPLEMENTS AND BREEDS FOR THE WHOLE LITTER (lb.)

Supplementation	Supplementation Began (Age)	Supplementation Ceased	n	8 Weeks	S.E.	100 lb.	S.E.	200 lb.	S.E.
Durocs									
Control			9 [1]	0.61	0.04	0.93	0.04	1.12	0.03
Aureo.	2 days	8 weeks	10	0.58	0.04	0.92	0.04	1.16	0.02
Aureo.	2 days	200 lb.	10	0.53	0.03	0.95	0.02	1.24**	0.02
Terra.	2 days	8 weeks	17	0.62	0.03	0.93	0.03	1.20*	0.02
Terra.	2 days	200 lb.	14	0.66	0.03	0.95	0.02	1.22**	0.02
Aureo.	4 weeks	8 weeks	3	0.66	0.07	1.03	0.06	1.23*	0.04
Aureo.	4 weeks	200 lb.	4	0.58	0.05	0.92	0.04	1.23*	0.04
Poland Chinas									
Control			17 [2]	0.52	0.07	0.82	0.04	1.06	0.03
Aureo.	2 days	8 weeks	11	0.58	0.06	0.88	0.04	1.12	0.03
Aureo.	2 days	200 lb.	12 [3]	0.57	0.06	0.93	0.03	1.18**	0.03
Terra.	2 days	8 weeks	7	0.42	0.08	0.82	0.06	1.08	0.04
Terra.	2 days	200 lb.	9	0.44	0.08	0.85	0.03	1.14*	0.03
Aureo.	4 weeks	8 weeks	3	0.60	0.11	0.93	0.08	1.17	0.06
Aureo.	4 weeks	200 lb.	2	0.60	0.12	0.96	0.06	1.24*	0.07
Terra.	4 weeks	8 weeks	6 [1]	0.56	0.08	0.89	0.06	1.12	0.04
Terra.	4 weeks	200 lb.	7 [1]	0.60	0.08	1.02	0.04	1.24**	0.04

[1] One pig died during the course of the experiment.
[2] Three pigs died during the course of the experiment.
[3] Two pigs died during the course of the experiment.
* Significantly different from the control group at the 5% level of probability.
** Significantly different from the control group at the 1% level of probability.

column of the table. Standard errors are also presented for the means of average daily gains, and significance of differences between the gains of the control pigs and supplemented pigs is indicated by one (5 percent level) or two (1 percent level) asterisks.

Both aureomycin and terramycin when fed during the entire suckling and growing-fattening period, or from 4 weeks of age to 200 pounds, increased the average daily gain significantly in each of the two breeds. The supplemented groups gained from 8 to 17 percent faster than the control pigs. There appears to be no difference between

the two antibiotics in the increased rates of gain achieved over the control.

It will be noted that, in general, the antibiotic supplementation when fed for the entire experimental feeding period increased the average daily gains to 200 pounds slightly more than when the antibiotic was fed for only the first 8 weeks of the feeding period. Under the conditions of these studies, this was more noticeable in the Poland China breed than in the Duroc breed. However, only one of the four differences between antibiotic supplementation for 8 weeks versus supplementation for the entire period was large enough (0.08) to be significant statistically.

TABLE 3. MEANS AND STANDARD ERRORS OF AVERAGE DAILY GAINS BY ANTIBIOTIC SUPPLEMENTATION FOR THE SPLIT LITTERS (lb.)

Treatment	n	8 Weeks	S. E.	100 lb.	S. E.	200 lb.	S. E.
Control	13	0.51	0.03	0.85	0.05	1.10	0.04
Terramycin [1]	12	0.59*	0.03	0.91	0.05	1.13	0.04
Aureomycin [1]	11	0.58*	0.03	0.89	0.05	1.08	0.04

[1] Supplementation given by capsule from birth to 4 weeks of age only.
* Significantly different from the control group at the 5% level of probability.

The standard errors of the means of average daily gains generally decrease from 8 weeks to 100 pounds and again to 200 pounds. This is due to litter differences in average daily gain, significant at 8 weeks and 100 pounds. Most of these differences are probably caused by variations in milking ability of the sows. After weaning, the litter differences rapidly diminished, so that in no case were they significant in causing variation in average daily gain for the entire feeding period.

Results of the second experiment are given in table 3. Since breed differences were not significant in this experiment, the average daily gains of the two breeds have been combined. The groups supplemented with terramycin and aureomycin from birth to 4 weeks of age gained significantly more than did the control group up to 8 weeks of age. These groups still showed slightly higher gains than the controls at 100 pounds. However, by the time the pigs had reached 200 pounds, there was little difference among the groups. The mean of average daily gains to 200 pounds was actually less in the aureomycin-supplemented group than for the control group. This was caused largely by one unthrifty pig in this lot.

The means of average daily gains for the two Duroc litters did not differ significantly at any of the three periods. Differences among the four Poland China litters were highly significant at 8 weeks and approached significance at 100 pounds. Small differences between litters remained at 200 pounds. These results also point out the importance of the sow during the early life of the pig.

The increase in the standard errors given in table 3 at 100 pounds and 200 pounds as compared to 8 weeks results from two causes. At 100 pounds the interaction of litters and rations was significant and the variation between pigs on the same ration increased from 100 to 200 pounds. The significant litter by ration interaction suggests that some litters may need antibiotic supplementation over a longer time than others to obtain the same gains.

Summary

Rations of Duroc and Poland China pigs were supplemented with crystalline aureomycin or crystalline terramycin for different growth periods. The supplements were started at 2 days or 4 weeks of age and stopped at either 4 weeks, 8 weeks, or 200 pounds.

Both antibiotics, when fed from 2 days or from 4 weeks of age to 200 pounds, were equally effective in inducing gains of from 8 to 17 percent more than for the controls in both breeds. The average daily gains for pigs that received antibiotic supplement for only the first 8 weeks were from 0.02 to 0.08 pound less than for those pigs receiving the supplement throughout the suckling, growing-fattening period.

Pigs receiving 2.5 mg. per day of either antibiotic from 2 days to 4 weeks of age gained 16 to 18 percent more up to weaning (8 weeks) than did the controls. However, by market time (200 pounds), the controls had gained about the same as the early supplemented groups. A significant interaction between litters and rations in this experiment suggests the possibility of differential responses to antibiotics supplementation due to effects which are common to littermates.

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THE EFFECT OF AN ANTIBIOTIC OR A SURFACTANT ON THE GROWTH AND CARCASS COMPOSITION OF SWINE [1]

T. W. Perry, W. M. Beeson and B. W. Vosteen [2]

Purdue University Agricultural Experiment Station

ANTIBIOTICS have been proven as a growth stimulant for growing and fattening swine by research conducted at many experiment stations in the United States and elsewhere. Similarly, certain surfactants have been reported to exert a growth-stimulating effect in swine (Luecke *et al.*, 1952) and poultry (Ely, 1951). However, the effect of this increased growth rate on the composition of carcasses produced has not been reported. Perry *et al.* (1950) reported that increased growth rate brought about by induced hyperthyroidism resulted in carcasses containing significantly increased ($P<.05$) fat and significantly decreased ($P<.05$) moisture, protein and ash. However, when the differences were analyzed by covariance to adjust for the differences in liveweight at time of slaughter, there was no significant difference between the two groups in moisture, protein, fat or mineral content.

The objective of this trial was to study the effect of stimulated growth rate, by an antibiotic or by a surfactant, on the composition of the carcasses produced.

Materials and Methods

Weanling crossbred pigs averaging 40 pounds liveweight were divided between three dry lots on the basis of liveweight and thrift. Lot I served as the control and was fed the 18 percent crude protein ration listed in table 1 at the beginning of the trial. As the pigs matured, the level of protein was adjusted accordingly. Lot II was fed the basal ration plus an aureomycin supplement at a level which contributed 7.5 milligrams aureomycin hydrochloride per pound of total ration. In Lot III the basal ration was modified by the addition of 0.26 percent alkyl benzene sulfonate product (26 percent alkyl benzene sulfonate mixed with a carrier composed of sodium sulfate, sodium chloride and sodium phosphate).

[1] Contribution from the Department of Animal Husbandry, Journal Paper No. 673, Purdue University Agricultural Experiment Station, Lafayette, Indiana.

[2] The authors are grateful to the Procter and Gamble Company, Cincinnati, Ohio, for supplying the alkyl benzene sulfonate.

TABLE 1. COMPOSITION OF BASAL RATION [1, 2]

	18% Protein	16% Protein
Corn	68.20	73.95
Soybean oil meal	26.35	20.60
Alfalfa meal	5.00	5.00
Vitamin A and D oil	0.25	0.25
Vitamin B_{12} supplement [3]	0.20	0.20
	100.00	100.00

[1] To each 100 pounds of total ration, the following additions were made: riboflavin 80 mg.; calcium pantothenate 450 mg.; niacin 500 mg.
[2] A free choice mineral mixture composed of 40% steamed bonemeal, 40% ground limestone, and 20% salt was available at all times.
[3] Vitamin B_{12} supplement contributed 10 micrograms B_{12} per pound of total ration.

Growth and feed consumption records were kept by 14-day intervals and the growth and feed data are presented in table 2. Although the animals from all three lots were slaughtered at the same liveweight (approximately 215 pounds), the growth and feed summaries had to be discontinued after 112 days because at that time some animals in each of the three lots had reached the selected weight for slaughter.

As each pig reached a liveweight of 185 pounds, a 20 ml. sample of blood was withdrawn by a needle and syringe from the jugular vein. The blood was centrifuged and the serum was analyzed for blood lipid content according to the method outlined by Allen (1938).

When each pig reached an approximate liveweight of 215 pounds, it was removed from its respective lot and was slaughtered. Standard

TABLE 2. THE EFFECT OF AN ANTIBIOTIC OR A SURFACTANT ON GROWTH, FEED CONSUMPTION, AND FEED EFFICIENCY
(112 Days)

Items Compared	Lot I Control	Lot II 7.5 mg. Aureomycin	Lot III 0.26% A.B.S.[1]
Number of pigs	8	8	8
Initial wt., lb.	40	41	40
Final wt., lb.	187	218	198
Gain per pig, lb.	147	177**	158
Daily gain per pig, lb.	1.31	1.60	1.41
Daily feed per pig, lb.	4.51	6.15	5.17
Feed per pound gain, lb.	3.44	3.84	3.67
Aureomycin per day	....	46 mg.	....
A.B.S.[1] per day	....	....	6.1 gm.

[1] A.B.S.—Alkyl benzene sulfonate—a surface active agent.
** Significant at the 1% level.
LSMD for gain, 5%, 18.9 lb.; 1%, 25.8 lb.

carcass measurements as outlined by the Association of Official Agricultural Chemists (1950) were made. In addition, all carcasses were analyzed for water, protein and fat content. These determinations were carried out in duplicate as outlined by the Association of Official Agricultural Chemists (1950). In order to obtain a representative sample from each carcass, one-half of each carcass was skinned, boned out and thoroughly ground and mixed in a sausage grinder. Bones, skin and carcass meat were weighed separately for each animal. A two-pound sample was taken for each ground carcass and the sample was thoroughly mixed in a Hobart Food Cutter before aliquots were taken for individual analysis. The data were analyzed by covariance to adjust for the slight difference in weight of the carcasses.

Results and Discussion

Influence of an Antibiotic or a Surfactant on Growth, Feed Consumption and Feed Efficiency

As summarized in table 2, the incorporation of 7.5 mg. aureomycin hydrochloride into the basal ration (Lot II) resulted in significantly increased ($P<0.01$) gain (30 pounds) over the average gain of the control animals. Animals which received 0.26 percent alkyl benzene sulfonate in the basal ration (Lot III) gained 11 pounds per pig more (approached significance) than the control animals, but gained 20 pounds less than animals fed antibiotics in their ration. No improvement in feed efficiency was brought about by adding either an antibiotic or a surfactant to the basal ration. Luecke *et al.* (1952) reported growth stimulation from a surfactant (Ethomid C-15) just as great as that obtained by the use of antibiotics.

Influence of an Antibiotic or a Surfactant on Blood Lipids

Although the blood lipid content at 185 pounds liveweight of surfactant-fed hogs (170 mg./100 ml.) and of antibiotic-fed hogs (160 mg./100 ml.) was higher than for the control animals (151 mg./100 ml.), the average difference between the three groups was not statistically significant. Dinusson *et al.* (1950) reported that treated beef heifers growing at a more rapid rate than control animals showed a significantly higher percent of blood lipids than control animals.

Influence of an Antibiotic or a Surfactant on Standard Carcass Measurements and Weight of Cuts

Bellies from one-half carcasses of antibiotic-fed hogs (13.6 lb.) were significantly heavier ($P<0.05$) than those from the carcasses of the

control animals (9.5 lb.). Also, the back fat thickness at the first rib for carcasses from the antibiotic-fed lot (61.9 mm.) and the surfactant-fed lot (58.0 mm.) was significantly greater ($P<0.01$ and $P<0.05$, respectively) than for the carcasses from the controls (54.1 mm.). This is in agreement with previous work by Vestal (1951) which showed that the feeding of antibiotics resulted in carcasses, from pigs weighing 224 pounds, of an average backfat measurement of 2.03 inches (80.0 mm.) as compared to 1.72 inches (67.8 mm.) from

TABLE 3. THE EFFECT OF AN ANTIBIOTIC OR A SURFACTANT ON MEASUREMENTS, CHEMICAL COMPOSITION OF CARCASSES, AND BLOOD LIPIDS

Items Compared	Lot I Control	Lot II 7.5 mg. Aureomycin	Lot III 0.26% A.B.S.[1]
Number of pigs	8	8	8
Av. liveweight, lb.	210	215	212
Av. chilled wt., lb.	147	154	148
Dressing percent	70.0	71.6	69.8
Av. weight of cuts (½ carcass)			
Back fat, wt., lb.	7.6	8.1	8.9
Belly wt., lb.	9.5	13.6*	11.0
Ham wt., lb.	13.5	13.6	11.1
Loin wt., lb.	10.4	10.0	9.9
Boston butt wt., lb.	4.6	4.7	4.4
Picnic wt., lb.	6.4	6.4	6.7
Edible meat, lb. (½ carcass)	55.4	60.6	57.2
Av. carcass measurements			
Leg length, cm.	51.7	49.6	50.2
Body length, cm.	75.4	73.6	74.8
Back fat thickness			
Last lumbar, mm.	45.0	50.0	46.0
Last rib, mm.	38.4	40.5	41.3
First rib, mm.	54.1	61.9**	58.0*
Av. edible carcass composition			
Crude protein, percent	11.1	9.4**	10.1*
Ether extract, percent	47.8	56.0**	53.5*
Moisture, percent	40.5	34.3**	36.2*
Av. blood lipids (184 pounds liveweight)			
Mg. percent blood lipids	151	160	170

LSMD Back fat thickness first rib, 5%, 4.62 mm.; 1%, 6.28 mm.
LSMD Belly wt., 5%, 3.0 lb.
LSMD Crude protein, 5%, 0.8%; 1%, 1.2%.
LSMD Ether extract, 5%, 4.45%; 1%, 6.06%.
LSMD Moisture, 5%, 3.2%; 1%, 4.4%.
[1] Alkyl benzene sulfonate.
* Significant at the 5% level.
** Significant at the 1% level.

pigs of the same liveweight at time of slaughter, but which received no antibiotic in their ration. Catron (1952) reported no difference in thickness of back fat between pigs fed antibiotics and pigs which were not fed antibiotics in their ration.

There were no other significant differences between the three groups for carcass measurements or weights of cuts.

Influence of an Antibiotic or a Surfactant on Chemical Composition of Carcasses Produced

The carcasses from the animals in Lot II (aureomycin) contained significantly ($P<0.01$) more fat (56.0%) and less protein (9.4%) and moisture (34.3%) than carcasses from the animals in Lot I, control (fat, 47.8%; protein, 11.1%; moisture, 40.5%). Carcasses from the animals in Lot III (Surfactant) also contained significantly ($P<0.05$) more fat (53.5%) and less protein (10.1%) and moisture (36.2%) than carcasses of the animals in Lot I.

Summary

Significantly increased growth rate was obtained by feeding 7.5 mg. aureomycin hydrochloride per pound of total ration ($P<0.01$) or 0.26 percent alkyl benzene sulfonate (approached $P<0.05$) in the ration of growing-fattening swine.

No increase in feed efficiency was brought about by the feeding of the antibiotic or the surfactant.

The blood from the more rapidly gaining antibiotic-fed or surfactant-fed hogs did not show significantly greater blood lipid than that from control-fed hogs when the blood was taken from all hogs at the same liveweight.

Back fat thickness at the first rib was significantly greater at the same kill weight for carcasses from swine which had been fed antibiotics ($P<0.01$) and for those fed surfactants ($P<0.05$) than for those carcasses from hogs fed the control ration.

The weights of bellies from the carcasses of antibiotic-fed hogs were significantly greater ($P<0.05$), at the same kill weight, than for bellies from the control animals.

Carcasses from antibiotic-fed hogs contained significantly more ($P<0.01$) fat and significantly less ($P<0.01$) protein and water than carcasses from the control animals. Carcasses from surfactant-fed hogs

likewise contained significantly more ($P<0.05$) fat and significantly less ($P<0.05$) protein and water than carcasses from the control animals.

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EFFECTS OF REDUCING AND DISCONTINUING AUREOMYCIN SUPPLEMENTATION DURING THE GROWING-FATTENING PERIOD OF PIGS FED CORN-PEANUT MEAL, CORN-SOYBEAN MEAL, AND CORN-COTTONSEED MEAL RATIONS [1]

H. D. WALLACE, L. T. ALBERT, W. A. NEY, G. E. COMBS and T. J. CUNHA

Florida Agricultural Experiment Station [2]

SINCE the first report of Jukes *et al.* (1950) appeared indicating that aureomycin stimulated growth of the pig, reports of a large number of similar studies for this and other antibiotics have been published. A recent survey of these experiments (Wallace *et al.*, 1952) revealed that aureomycin, terramycin, penicillin, streptomycin, and bacitracin all were effective growth stimulants. Their effectiveness varied with several factors; these included disease level, adequacy of control ration, and size of the animals. It is generally agreed that young animals respond more strikingly to antibiotic supplementation. This was confirmed by the survey.

Using a mixed plant and animal protein ration, Hanson *et al.* (1950) observed that withdrawal of aureomycin, terramycin, and penicillin at 125 pounds resulted in an adverse effect on feed consumption and rate of growth. Wilson (1952) reported that when aureomycin and terramycin were removed from the ration at 125 pounds, only a slight depression of growth was observed. He self-fed shelled corn and a protein supplement containing soybean meal, tankage, and alfalfa meal. Intermittent feeding of aureomycin (Burnside, 1952) resulted in poorer gains than when the antibiotic was present in the plant protein ration for the entire growing-fattening period.

The studies reported here were undertaken to determine the feasibility of reducing and discontinuing the supplementation of aureomycin after animals pass the critical growth period and weigh over 100 pounds.

Experimental Procedure

Purebred Duroc, Duroc × Spotted Poland China, and purebred Hampshire pigs averaging between 100 and 155 pounds served as

[1] Florida Agricultural Experiment Station Journal Series, No. 133. Supported in part by a grant from the National Vitamin Foundation, Inc., and the Lasdon Foundation, Inc.

[2] Department of Animal Husbandry and Nutrition, Gainesville, Florida.

experimental animals for the various tests. All animals were weaned off pasture at 8 weeks of age and then fed in dry lot on the various plant-protein type rations under study until they reached the desired weight. A source of aureomycin was available to all pigs during the growth period prior to placing them on the desired treatments at 100 to 155 pounds.

Allotment of the experimental animals was based on breed, weight, previous treatment, and previous gains. They were maintained on concrete floors which were washed daily. Water and feed were provided

TABLE 1. COMPOSITION OF RATIONS

	Peanut Meal Ration [1]	Soybean Oil Meal Ration [2]	Cottonseed Oil Meal Ration [2]
Corn	56.5	72.0	73.0
Peanut meal	41.5	....	....
Soybean meal	....	21.0	....
Cottonseed meal	....	....	25.0
Limestone	1.0	1.0	1.0
Steamed bonemeal	0.5	0.5	0.5
Salt-trace mineral mixture [3]	0.53	0.53	0.53

[1] The following vitamins were added per 100 pounds of feed: thiamine 1 gm.; riboflavin 230 mg.; niacin 2.33 gm.; pantothenic acid 1.0 gm.; pyridoxine 375 mg.; choline 19.4 gm.; and folic acid 22.7 mg.

[2] Lederle Fortafeed 249-C added at the rate of 2 pounds per ton.

[3] Iodized salt 50 pounds, manganese sulfate 921 gm.; ferrous sulfate 398 gm., copper sulfate 125 gm., and cobalt carbonate 10 gm.

ad libitum. The experimental rations used are listed in table 1. Growth data were treated statistically by the analysis of variance.

Results and Discussion

Corn-Peanut Meal Ration

Results of two experiments are shown in table 2. Reduction of the level of aureomycin from 20 grams per ton to 10 grams per ton did not interfere with subsequent gains (Experiment I, Lot 2). However, when the aureomycin was discontinued entirely (Lot 3), gains were significantly depressed. Considerable diarrhea was observed in Lot 3 during the first 2 weeks after removal of the aureomycin, and it was necessary to remove one animal from the test because of severe diarrhea. Appetites were also depressed as evidenced by the drop in average daily feed consumption (Lot 3). Animals on the reduced level

TABLE 2. EFFECT OF REDUCING AND DISCONTINUING AUREOMYCIN SUPPLEMENTATION DURING THE GROWING-FATTENING PERIOD OF PIGS FED A CORN-PEANUT MEAL RATION [1]

Item	Experiment I [2]			Experiment II [3]		
	Lot 1 Control 1.0 gm. Aureomycin per 100 lb. Feed	Lot 2 Reduced 0.5 gm. Aureomycin per 100 lb. Feed	Lot 3 Discontinued No Aureomycin	Lot 1 Control 1.0% Aurofac [4]	Lot 2 Reduced 0.5% Aurofac	Lot 3 Discontinued No Aurofac
No. pigs	11 [5]	11	10 [6]	7	7	7
Days on experiment	49	49	49	56	56	56
Av. initial wt., lb.	111.2	109.7	108.9	104.1	103.4	103.7
Av. final wt., lb.	186.5	185.5	158.4	201.0	200.1	184.1
Av. daily gain, lb.	1.54	1.55	0.99*	1.73	1.73	1.44*
Standard error, daily gain, lb.	0.15	0.08	0.18	0.07	0.08	0.06
Av. daily feed, lb.	5.1	5.4	4.1	6.8	7.0	6.2
Pounds feed per 100 lb. gain	316	353	401	396	405	432

* Significantly slower than other treatments at 5% level of probability.

[1] The aureomycin hydrochloride, Aurofac, and crystalline B-vitamins used in these and the other trials were generously supplied through the courtesy of Dr. T. H. Jukes, Lederle Laboratories, Pearl River, New York.

[2] Animals in this experiment had received 1.0 gm. aureomycin per 100 lb. feed from weaning to start of this trial except for two pigs in each lot which had received 1.0 gm. terramycin.

[3] Animals in this experiment had received 1.0% Lederle Aurofac from weaning to start of this test.

[4] This product contained a minimum of 1.8 gm. of aureomycin and 1.8mg. B_{12} per pound.

[5] One pig removed after 3 weeks because of failure to gain and dermatitis.

[6] One pig removed after 1 week because of severe diarrhea and vomiting.

of aureomycin (Lot 2) had better appetites than those on the control ration (Lot 1) but were less efficient in the utilization of feed.

In Experiment II, Aurofac (vitamin B_{12}-aureomycin supplement) was fed as a source of antibiotic. All pigs in this experiment performed better than those of Experiment I. Nevertheless, the same general trend was apparent in their gains, feed consumption, and feed utilization. Reduction of the aureomycin from approximately 36

TABLE 3. EFFECT OF DISCONTINUING AUREOMYCIN SUPPLEMENTATION DURING THE GROWING-FATTENING PERIOD OF PIGS FED A CORN-SOYBEAN MEAL RATION [1, 2]

Item	Experiment I		Experiment II	
	Lot 1 Control 0.5% Aurofac [3]	Lot 2 Discontinued No Aurofac [4]	Lot 1 Control 0.5% Aurofac [3]	Lot 2 Discontinued No Aurofac [4]
No. pigs	8	8	6	6
Days on experiment	56	56	49	49
Av. initial wt., lb.	104.3	116.7	116.3	116.5
Av. final wt., lb.	180.4	191.0	198.6	190.1
Av. daily gain, lb.	1.35	1.32	1.68	1.58
Standard error, daily gain, lb.	0.07	0.06	0.03	0.04
Av. daily feed, lb.	5.2	6.1	7.3	6.6
Pounds feed per 100 lbs. gain	389	461	433	436

[1] The soybean oil meal was a 44% solvent processed meal purchased on the open market.
[2] Animals had received 0.5% of Aurofac in their rations from weaning to start of these experiments.
[3] Aurofac contained a minimum of 1.8 gm. aureomycin and 1.8 mg. B_{12} per lb.
[4] B_{12} added at rate of 0.9 mg. per 100 lb. feed to compensate for that supplied by Aurofac.

grams per ton to 18 grams per ton (Lot 2) did not affect subsequent gains, while complete removal of the antibiotic (Lot 3) significantly depressed growth. Again, the animals on the reduced level (Lot 2) consumed the most feed per day but were slightly less efficient in the utilization of the feed.

Corn-Soybean Meal Ration

Results of two experiments are shown in table 3. Gains of pigs in Experiment I were abnormally slow. No effect on gains was observed when the source of antibiotic was removed. However, there was a marked difference in feed efficiency in favor of the group that continued to get aureomycin. A 100-pound total initial weight allotment

error between the two groups may have been partially responsible for the irregularities which seemed apparent in this particular test. The heavier animals of Lot 2 would normally have gained faster, but actually they made the same gains, thus indicating again a possible growth depressing action with removal of the antibiotic. The heavier animals would also be expected to consume more feed per day and to be less efficient converters of feed, other factors being equal. The results show this to be true. In Experiment II, it was

TABLE 4. EFFECT OF DISCONTINUING AUREOMYCIN SUPPLEMENTATION DURING THE GROWING-FATTENING PERIOD OF PIGS FED A CORN-COTTONSEED MEAL RATION [1]

Item	Treatment	
	Lot 1 Control 0.5% Aurofac [2]	Lot 2 Discontinued No Aurofac [3]
No. pigs	7	7
Days on experiment	28	28
Av. initial wt., lb.	153.5	153.9
Av. final wt., lb.	213.7	197.5
Av. daily gain, lb.	2.21	1.56**
Standard error, daily gain, lb.	0.12	0.17
Av. daily feed, lbs.	8.3	7.2
Pounds feed per 100 lbs. gain	388	467

** Gains significantly slower at 1% level of probability.

[1] The cottonseed meal was a low-gossypol meal processed by the Southern Regional Laboratory, New Orleans, Louisiana.

[2] Aurofac contained a minimum of 1.8 gm. of aureomycin and 1.8 mg. B_{12} per lb.

[3] B_{12} added at rate of 0.9 mg per 100 lb. feed to compensate for that supplied by Aurofac.

observed that removal of the antibiotic (Lot 2) resulted in slower gains, but the difference was not statistically significant. Appetites were depressed, as indicated by average daily feed consumption figures, while there was no important difference in feed utilization.

Corn-Cottonseed Meal Ration

Results of one experiment involving a corn-low gossypol cottonseed meal ration are shown in table 4. In this test, the animals were carried to a weight of over 150 pounds before the antibiotic was withdrawn. Withdrawal of the antibiotic caused a highly significant growth depressing effect, reduced daily feed consumption, and resulted in much poorer utilization of feed.

Summary

1. Five experiments were conducted to determine the feasibility of reducing the level of aureomycin supplementation and the feasibility of completely withdrawing aureomycin from the ration of growing-fattening pigs after they have passed the critical period of growth.

2. In two tests involving a corn-peanut meal ration, gains were not influenced by reducing the level of aureomycin from 20 grams to 10 grams per ton, and from 36 grams to 18 grams per ton. However, animals on the lower levels ate more feed per day, indicating that appetites may have been improved with a reduction in the amount of antibiotic. Nevertheless, in both tests feed utilization figures were in favor of the group that remained on the high level of antibiotic. Complete withdrawal of the aureomycin caused significant slowing of gains, lower feed consumption, and poorer feed conversion in these two tests as well as in one in which the ration consisted of corn-cottonseed meal. In two other experiments involving a corn-soybean meal ration, the effects of withdrawing aureomycin were less pronounced but still apparent.

3. Evidence is provided indicating that antibiotic supplementation should not be discontinued during the growing-fattening period of the pig if optimum gains are to be obtained.

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EFFECTS OF INJECTION OF TESTOSTERONE, ESTRADIOL AND A COMBINATION OF THE TWO UPON GROWING-FATTENING SWINE [1]

R. B. Sleeth,[2] A. M. Pearson, H. D. Wallace, D. H. Kropf and Marvin Koger [3]

Florida Agricultural Experiment Station [4]

RECENTLY there has been much interest in the effect of the various sex hormones upon growth and fattening processes. Much of the information available is conflicting and inconclusive. Working with rats, Rubinstein and Solomon (1940) reported testosterone injections increased gains in body weight, whereas other researchers reported it to be without effect (Shay *et al.*, 1941) or to inhibit growth (Turner, Lachman and Hellbaum, 1941; Rubinstein, Kurland and Goodwin, 1939; Korenchevsky, Dennison and Hall, 1937a, b; Simpson *et al.*, 1944). Bergetrand (1950) reported that testosterone increased the growth rate of rabbits. Dinusson, Andrews and Beeson (1950) reported that testosterone did not have any measurable effect upon the gains of heifers, while Andrews, Beeson and Johnson (1950) reached similar conclusions in regard to steers. O'Mary *et al.* (1951) reported testosterone pellets to be without effect on fattening lambs, while Woehling *et al.* (1951) obtained similar results with swine. On the other hand, Bogart et al. (1951, 1952) concluded that testosterone injections at the rate of 1 mg. per kg. of body weight weekly increased the rates of gain and improved the efficiency of feed utilization with both steers and heifers.

Several experiments have been reported (Deanesly, 1939; Hooker and Pfeiffer, 1943) indicating that estradiol has a marked depressing action upon weight gains of treated rats. Odendaal (1942) reported that female rats given estradiol gained more rapidly for the first 3-week period, but no difference occurred thereafter. Working with cockerals, Salomon *et al.* (1947) reported estradiol caused inhibition of growth.

This study was undertaken to ascertain the effects of testosterone,

[1] Florida Agricultural Experiment Station Journal Series, No. 132.

[2] A portion of a thesis presented by the senior author to the Graduate Faculty, University of Florida, in partial fulfillment of requirements for the Master of Science degree in agriculture.

[3] The authors wish to express their thanks to Dr. Preston L. Perlman of the Schering Corporation for providing the estradiol benzoate and testosterone propionate, and to Dr. T. H. Jukes of Lederle Laboratories for the Aurofac.

[4] Department of Animal Husbandry and Nutrition, Gainesville.

estradiol and a combination of the two upon rate of gain, feed requirement per unit of gain and certain cracass characteristics of growing-fattening swine.

Experimental Procedure

Experiment I

Fourteen purebred Duroc and Hampshire pigs were divided equally into two lots, insofar as possible, on a basis of weight, sex and breed. The pigs were started on feed in dry lot on December 29, 1951, but were put on oat pasture February 1, 1952, as they appeared unthrifty

TABLE 1. RATION USED [1]

Ingredients	Parts
Corn, ground	60.0
Soybean oil meal	28.0
Alfalfa meal	5.0
Meat and bone scraps (55% protein)	5.0
Limestone	1.0
Bone meal	0.5
Salt-trace mineral mixture [2]	0.53
	100.03

[1] Aurofac was added at the rate of 0.5 pound per 100 pounds of ration (1.8 gm. aureomycin and 1.8 mgm. B_{12} per pound).

[2] Salt-trace mineral mixture was composed of iodized salt 50 pounds, manganese sulfate 800 gm., ferrous sulfate 398 gm., copper sulfate 125 gm., and cobalt carbonate 10 gm.

and were making poor gains. They soon commenced making good gains on pasture and the trial was concluded after a total of 115 days had elapsed. All pigs were self-fed the same ration (table 1) and had free access to water. Weights were taken weekly and records of feed consumption were kept. A summary of the feeding trial is found in table 2.

The pigs in Lot 1 served as the untreated controls, while those in Lot 2 were injected with testosterone propionate at the rate of 1 mg. per kg. of body weight once weekly for 6 weeks and semi-weekly thereafter.

The increase in frequency of dosage was apparently not harmful, as the weekly weights did not appear to show any wider fluctuations than previously.

At the close of the feeding trial, all pigs were slaughtered in the University Meats Laboratory. Although carcass weights were taken,

the scale was found to be out of order, making an error of considerable magnitude. As a result, carcass weights and yields cannot be reported for Experiment I. Thickness of back fat was determined by averaging the measurements at the first rib, last rib, and last lumbar vertebra. The carcass length from the first rib to the aitch bone was measured and recorded. Reproductive organs were observed for any abnormalities.

Wholesale loins were taken from all carcasses and two roasts were

TABLE 2. SUMMARY OF EXPERIMENT I

	Lot 1 Control	Lot 2 Testosterone [1]
Number of pigs [2]	7	7
Number days on feed	115	115
Av. initial wt., lb.	35.1	35.4
Av. final wt., lb.	196.3	178.9
Av. daily gain, lb.	1.40	1.25
Pounds feed required per 100 lb. gain	378	379
Av. thickness of back fat, inches [3]	1.57	1.48
Av. carcass grade [4]	C-1	Med.
Av. carcass length,[5] inches	27.9	26.8
Av. palatability score [6]	4.54	4.51
Av. shear reading,[7] lb.	4.22	3.19

[1] Testosterone propionate was injected into the ham.
[2] Number of pigs—Lot 1—2 barrows and 5 gilts.
Lot 2—3 barrows and 4 gilts.
[3] Av. thickness of back fat was determined by averaging measurements recorded at first rib, last rib, and last lumbar vertebra.
[4] Carcass grades based on new U. S. Government grades:
Choice 1—C-1 Medium—Med.
Choice 2—C-2 Cull—Cull
Choice 3—C-3
[5] Carcass length was measured from 1st rib to forward point of aitch bone.
[6] Av. palatability score was average of 12 judges' scores on roast from each pig. Basis of scoring was from one to seven in order of increasing desirability.
[7] Shear readings were made on ½-inch cores and recorded in pounds required to shear core with three cores per roast and three shears per core.

removed adjacent to the shoulders. The roasts were placed in freezer-storage of 0°F. and held until removed for testing on the fourth or fifth day.

All roasts were cooked in an electric oven as 350°F. to an internal temperature of 185°F. Weights were taken before and after cooking. One roast from each animal was used for palatability tests.

The palatability panel was composed of six girls, who had been carefully screened on a basis of threshold test, and six staff members having previous experience. Organoleptic tests were made on seven roasts for two consecutive days, with treatment being randomized between meetings. Each roast was rated by all judges for aroma,

flavor of fat, flavor of lean and tenderness. The results of the carcass studies are summarized in table 2.

Experiment II

Forty purebred Duroc and Hampshire pigs, weighing approximately 46 pounds, were divided into four lots of 10 pigs. Each lot was composed of five barrows and five gilts. Starting July 1, 1952, all lots were self-fed on pasture for a total of 112 days using the ration shown in table 1 with exception of the fact that Aurofac was not added.

The pigs in Lot I served as untreated controls, those in Lot II were injected intramuscularly with testosterone propionate semi-weekly at

TABLE 3. SUMMARY OF STATISTICAL ANALYSIS FOR EXPERIMENT I
(Sums of Squares)

Source of Variation	Degrees of Freedom	Thickness of Back Fat	Tenderness Shear Test	Palatability Scores	Carcass Length	Av. Daily Gain
Total	13	0.91	19.98	0.550	26.18	0.40
Sex	1	0.02	0.25	0.180**	0.57	0.00
Treatment	1	0.03	3.74	0.004	4.57	0.08
Subgroups	3	0.08	4.00	0.218	5.00	0.09
Error term	8	0.78	11.99	0.148	16.04	0.23

** Significant at the 1% level.

the rate of 0.5 mg. per kg. of body weight, those in Lot III were injected in the same manner with 1.0 mg. per kg. of body weight of estradiol benzoate, while the animals in Lot IV were injected with 0.5 mg. of testosterone propionate and 1.0 mg. of estradiol benzoate per kg. of body weight.

The animals were slaughtered by a local packer at the end of the experiment. Carcass measurements were taken as explained in Experiment I. Cold carcass weights were obtained and dressing percentages were calculated as explained in the footnotes to table 4. The wholesale loins were removed from two barrows and two gilts in each lot. Palatability ratings and tenderness were determined as outlined in Experiment I. The results of Experiment II are summarized in table 4.

Results and Discussion

Average Daily Gains

In Experiment I the pigs receiving the testosterone (Lot 2) gained 1.25 pounds per day, as compared with 1.40 pounds for the controls (Lot 1). The difference between lots was not statistically significant

because of the wide variability in gain observed between individual pigs in each lot.

In the second experiment (table 4) the control pigs gained an average of 1.36 pounds per day, compared with 1.30 for those receiving testosterone, 1.32 for those getting estradiol and 1.16 for those injected with a combination of estradiol and testosterone. Although the difference between the control animals and those receiving the combination of hormones amounted to 0.2 pound per day, the wide variation in

TABLE 4. SUMMARY OF RESULTS FOR EXPERIMENT II

Treatment	Lot 1 Control	Lot 2 Testosterone	Lot 3 Estradiol	Lot 4 Combination
Number of pigs [1]	10	10	10	10
Days on trial	112	112	112	112
Av. initial wt., lb.	46.3	46.5	46.5	46.5
Av. final wt., lb.	198.1	192.1	194.4	177.7
Av. daily gain, lb.	1.36	1.30	1.32	1.16
Pounds feed required per 100 lb. gain	420	366	318	331
Av. dressing percentage [2]	76.33	76.73	76.35	77.12
Av. thickness of back fat,[3] inches	1.69	1.64	1.68	1.45
Av. carcass grade [3]	C-1	C-1	C-1	C-1
Av. carcass length,[3] inches	28.1	28.2	28.4	27.4
Av. shear reading,[3] lb.	3.26	4.01	3.77	4.06
Av. palatability score [3]	4.29	4.39	4.19	4.06

[1] Five barrows and five gilts in each lot.

[2] Dressing percentage $= \frac{\text{chilled carcass wt (shipper style)} \times 100}{\text{final wt.}}$

[3] See footnotes of table 3 for explanation of these items.

the response of individual animals in each lot made the differences between lots not statistically significant. As some pigs in each lot made excellent gains whereas others gained much more slowly, it appears that the sex hormones had no effect upon gains in body weight.

Feed per Hundred Pounds Gain

The amount of feed required per hundred pounds of gain was 378 pounds for Lot 1 (controls), compared with 379 pounds for Lot 2 (testosterone). In the second trial, the control pigs used 420 pounds, as compared with 366 for those getting testosterone, 318 for those getting estradiol and 331 for the lot receiving a combination of testosterone and estradiol. The fact that more feed wastage was apparent

in Lot 1 (controls) of Experiment II makes the data of doubtful significance, especially so because no difference occurred between the animals receiving testosterone and the controls in Experiment I. Although the data are not conclusive, differences in feed requirements per unit of gain are apparent in table 6.

Sexual Behavior and Appearance of Sex Organs

The gilts receiving estradiol showed marked enlargement of the external genitalia, restlessness and other signs of estrus within 12 hours from the time of injection. Both gilts and barrows exhibited marked enlargement of the teats, which resulted in the manifestation of slight to extreme seediness of the bellies. The seminal vesicles and

TABLE 5. STATISTICAL ANALYSES SUMMARY FOR EXPERIMENT II
(Sums of Squares)

Source of Variation	Degrees of Freedom	Thickness of Back Fat	Length of Carcass	Dressing Percentage	Av. Daily Gains	Tenderness Shear Test [1]	Palatability Scores [1]
Total	39	4.31	89.75	211.79	1.64	(15) 14.40	(15) 0.70
Sex	1	0.25	2.76	6.68	0.10	(1) 0.88	(1) 0.06
Treatment	3	0.35	4.24	4.77	0.20	(3) 1.80	(3) 0.23
Subgroups	7	0.61	11.28	14.71	0.39	(7) 5.54	....
Sex × treatment	3	0.01	4.28	3.26	0.09	(3) 2.86	....
Error term	25	3.09	67.19	182.37	0.86	(1) 3.32	(11) 0.41

[1] Smaller numbers were used on palatability and shear test so degrees of freedom are given in parentheses preceding the sums of squares.

prostates were apparently normal in the barrows, while the reproductive organs from the gilts showed marked atrophy and the ovaries were extremely cystic.

The animals receiving testosterone alone, both barrows and gilts, rode each other frequently and ranted in a typical boar-like manner. Otherwise, the animals exhibited no outward manifestation of effects of the treatment. They were somewhat trimmer and neater in the underline, with no tendency for production of seedy bellies. The ovaries from the gilts were enlarged and cystic, while the entire genital tracts showed marked hyperemia and hyperplasia. The seminal vesicles and prostate glands from the barrows receiving testosterone ranged from normal to slightly enlarged and hardened.

The teats on the pigs receiving a combination of testosterone and estradiol were normal in appearance and showed no increased tendency above the controls towards seediness of bellies. Frequent riding was manifested by both barrows and gilts. In general, the reproductive

tracts from the gilts were juvenile in appearance, and the ovaries were most frequently degenerated, though an occasional cyst was present.

Palatability Scores and Shear Readings

In both Experiments I and II, palatability scores indicated that the use of hormones had no effect upon desirability of the meat from the standpoint of either aroma, flavor, or tenderness. It was impossible to detect off-odors during slaughtering or cooking. This indicates that the sex hormones used in this investigation are not responsible for the "boar-flavor or odor" *per se*.

TABLE 6. FEED REQUIREMENT PER UNIT OF BODY WEIGHT SUMMARY, EXPERIMENTS I AND II

	Feed Required per 100 lb. Gain
Control [1]	399
Testosterone [1]	372
Estradiol [2]	318
Combination—estradiol and testosterone [2]	331

[1] Average of both experiments.
[2] Data obtained in Experiment II only.

In Experiment I (table 3), there was a highly significant difference between the palatability scores of the barrows and gilts. No reason is apparent for this difference, and since it appears to be independent of treatment and could not be verified in other trials, it is apparently due to chance.

The differences in shear strength between lots were small and were not significant. However, in order to test the validity of the shear tests, the coefficient of correlation between shear values and organoleptic scores for tenderness was calculated and found to be highly significant ($r=0.495$).

Thickness of Back Fat and Dressing Percentage

Although the control carcasses had slightly thicker back fat than the hormone-treated animals in both experiments, the differences were not statistically significant.

The dressing percentages in Experiment II (table 4) varied from 76.33 percent for the controls (Lot 1) to 77.12 percent for the combination of estradiol and testosterone (Lot 4). The mean differences were small and, as would be expected, were not statistically significant.

Carcass Length and Carcass Grade

The average carcass length was 27.9 inches for the controls and 26.8 for the lot receiving testosterone in Experiment I. In the second trial, the average length varied from 27.4 inches for Lot 4 (combination of estradiol and testosterone) to 28.4 inches for Lot 3 (estradiol). Statistical analysis revealed the differences in both experiments to be of no significance.

Although the control lots had slightly more back fat in both experiments, the average carcass grades were similar. Even in the first trial when the average grade for the testosterone lot was medium compared with Choice No. 1 for the controls, the difference in grade was borderline and little significance can be attached to it.

Summary

Two experiments involving a total of 54 pigs were conducted to determine the effects of intramuscular injections of testosterone, estradiol and a mixture of the two upon average daily gains, efficiency of gains and certain carcass measurements of growing-fattening pigs. At the level used, neither testosterone, estradiol nor a combination of the two appeared to influence significantly rate of gain, carcass length, carcass grade, dressing percentage, thickness of back fat, palatability of roasts or tenderness as measured by the Warner-Bratzler shear. Both treated barrows and gilts exhibited an abnormal sexual behavior and the reproductive tracts showed the effects of marked hormonal stimulation. The data on efficiency of gains are inconclusive.

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EFFECT OF STILBESTROL ON RATION DIGESTIBILITY AND ON CALCIUM, PHOSPHORUS AND NITROGEN RETENTION IN LAMBS

C. K. WHITEHAIR,[1] WILLIS D. GALLUP and M. C. BELL[2]

Oklahoma Agricultural Experiment Station[3]

INFORMATION relating the effect of synthetic estrogens to metabolism is of fundamental interest in nutrition and may have practical implications in certain metabolic changes in livestock.

Early evidence of the effect of estrogens on the metabolism of such nutrients as calcium, phosphorus and nitrogen is reviewed by Gardner and Pfeiffer (1943). More recent work has confirmed and extended these observations specifically with respect to the effects on calcium (Govaerts, Dallemagne and Melon, 1951) and phosphorus metabolism (Taurog *et al.*, 1944; Govaerts and Dallemagne, 1948). In certain metabolic disturbances of man, the estrogens have been shown to increase calcium, phosphorus and nitrogen retention (Albright and Reifenstein, 1948; Schilling *et al.*, 1950; Harris and Thiman, 1946).

In chickens, the injection of stilbestrol has been found to improve carcass quality and to increase fat deposition (Lorenz, 1943, 1945). Recent studies by Lorenz and Bachman (1947) have shown that fat deposition may be stimulated without the development of the lipemia observed in earlier work (Lorenz, Chaikoff and Entenman, 1938). Shipley *et al.* (1950) have shown that estrone has a lipotropic effect when fed to intact and castrated female rats on a diet which produces fatty liver. These workers suggest that the lipotropic action is dependent on an extra-hepatic rather than a direct hepatic effect.

Andrews, Beeson and Harper (1949) and Jordan (1950) reported that the subcutaneous implantation of stilbestrol pellets increased the rate of gain and feed efficiency of feeder lambs. A similar effect was noted in beef heifers by Dinusson, Andrews and Beeson (1950). The latter workers also noted a slight increase in blood inorganic phosphorus. Serum calcium and blood lipid content were similar in the stilbestrol-treated and control animals. Folley (1936) reported that in the lactating cow administration of oestrogenic hormone caused a temporary fall in serum calcium and a temporary rise in serum phosphatase. Sellers

[1] Present address, University of Illinois, Urbana.
[2] Present address, University of Tennessee, Knoxville.
[3] Departments of Animal Husbandry and Agricultural Chemistry Research. The authors are indebted to Professor Carl E. Marshall for statistical analysis of the data in this paper.

and Roepke (1951) also found that estrogens administered to cows in late pregnancy caused a slight decrease in serum calcium. The effect was most marked and consistent at parturition, at which time serum inorganic phosphorus also decreased.

In the experiment reported here, the effect of subcutaneous implantation of stilbestrol pellets on digestion, and on nitrogen, calcium and phosphorus balance, was investigated with lambs.

Experimental

Ten wether feeder lambs (Suffolk rams × range ewes) were selected for this study. The lambs had been used in a previous digestion trial and were accustomed to the conditions imposed by metabolism studies. Their average weight at the start of the experiment was 69.2 pounds. The experiment was conducted during the summer of 1951.

Two standard 10-day digestion and nitrogen, calcium, and phosphorus balance trials were conducted. A 24-day preliminary period preceded trial I to allow the lambs to become accustomed to the ration. A 10-day preliminary period immediately following this trial preceded trial II. During the preliminary period of each trial the lambs were maintained together in a small pen with facilities for individual feeding.

A constant amount of the experimental ration was fed twice daily to each lamb during the entire experiment. The daily ration was: coarsely ground prairie hay 360 grams, ground corn 410, soybean oil meal 129, iodized salt 8, and calcium carbonate 3. The average percentage chemical composition of the ration on a dry matter basis was as follows: ash 6.0, protein 12.6, ether extract 3.7, crude fiber 16.2, N-free extract 61.5, calcium 0.47 and phosphorus 0.45.

At the start of the experiment the lambs were divided, according to weight, into two groups. During the preliminary and collection periods of trial I both groups were fed the same ration and cared for in the same manner. Immediately following this trial, the five lambs in one group were each given two 12-mg. stilbestrol pellets [4] implanted subcutaneously in the neck region. The other group which served as a control was left untreated. Ten days later the second digestion and balance trial (trial II) was started.

The manner of conducting the balance trials and the chemical analyses of urine and feces were essentially the same as described in

[4] The authors express their appreciation to Wick and Fry, Inc., for the stilbestrol pellets used in this experiment.

previous reports from this station (Gallup, Briggs, and Hatfield, 1950; Gallup and Briggs, 1950).

Results and Discussion

The results are summarized in tables 1, 2, and 3. During trial I one lamb refused to eat a constant amount of ration and was eliminated from the experiment.

Table 1 gives the results obtained in determining the possible effect of stilbestrol on the digestibility of ration nutrients. A slight increase in the digestibility of crude fiber by the stilbestrol-treated lambs was the only effect noted.

TABLE 1. AVERAGE DIGESTIBILITY OF RATION

Group	Trial No.	Number of Lambs	Apparent Digestibility of Dry Matter	Organic Matter	Protein	Ether Extract	Crude Fiber	N-free Extract
			%	%	%	%	%	%
Control	I	4	73.2	73.2	69.1	76.1	60.0	79.3
	II	4	71.6	73.6	67.9	73.0	62.4	77.9
Experimental	I	5	71.1	73.1	66.2	72.5	61.8	77.4
	II	5 [1]	73.3	75.1	69.0	73.3	65.9	78.9

[1] Stilbestrol during trial II.

Table 2 gives the average daily calcium, phosphorus, and nitrogen balance for each group of lambs during each trial. There was a marked decrease in the amount of calcium excreted in both the feces and urine of the lambs treated with stilbestrol. Calcium retention, which in the control lambs increased from 0.62 gm. in trial I to 1.33 gm. in trial II, increased from 0.27 gm. in lambs before treatment with stilbestrol to 2.09 gm. after treatment. Thus, during trial II the treated lambs retained nearly 60 percent more calcium than the controls.

Phosphorus retention also was increased in the stilbestrol-treated lambs. Decreased fecal excretion of phosphorus accounted for this increase, urinary excretion being low in all trials. In the treated lambs of trial II, phosphorus retention was increased 34 percent above that of the same untreated lambs in trial I and 30 percent above that of the control lambs in both trials.

Nitrogen retention in the stilbestrol-treated lambs increased from

TABLE 2. AVERAGE CALCIUM, PHOSPHORUS AND NITROGEN BALANCE ON A DAILY BASIS (GRAMS)

Trial Group	Number of Lambs	Intake				Fecal Excretion			Urinary Excretion			Retention [2]		
		Dry Matter	Ca	P	N	Ca	P	N	Ca	P	N	Ca	P	N
Control														
I	4	821.0	3.81	3.67	16.57	2.87	1.72	5.13	0.32	0.05	7.69	0.62	1.90	3.75
II	4	821.0	3.97	3.65	16.64	2.45	1.69	5.35	0.19	0.07	7.81	1.33	1.89	3.48
Experimental														
I	5	820.0	2.81	3.67	16.57	3.27	1.81	5.60	0.27	0.02	7.88	0.27	1.84	3.09
II [1]	5	820.0	3.97	3.65	16.64	1.81	1.15	5.16	0.07	0.04	5.82	2.09	2.46	5.66

[1] Stilbestrol during trial II.

[2] Differences between the control and stilbestrol-treated lambs in retention of calcium, phosphorus and nitrogen during trial II were significant at the 1 percent level.

3.09 gm. before treatment to 5.66 gm. after treatment. This increase of 83 percent ascribed to stilbestrol treatment was effected through a marked decrease in the amount of nitrogen excreted in the urine. Increased efficiency of utilization of absorbed nitrogen was thereby indicated. Nitrogen retention by the control lambs varied only slightly between trials and in trial II was 38 percent less than that retained by the treated lambs.

TABLE 3. EFFECT OF STILBESTROL ON RATE OF GAIN

Items	Control Group of 4 Lambs	Experimental Group of 5 Lambs
(Trial I, including 24 days preliminary and 10 days collection)		
Treatment	none	none
Av. initial wt., lb.	67.75	69.2
Av. final wt., lb.	73.25	75.2
Gain per lamb, lb.	5.5	6.0
Av. daily gain, lb.	0.16	0.176
(Trial II, including 10 days preliminary and 10 days collection)		
Treatment	none	stilbestrol
Av. initial wt., lb.	73.25	75.20
Av. final wt., lb.	77.75	82.80
Gain per lamb, lb.	4.5	7.6
Av. daily gain, lb.	0.225	0.38 [1]

[1] Difference in gain in favor of the stilbestrol-treated lambs was significant at the 5 percent level.

The increased utilization of calcium and phosphorus effected by stilbestrol confirms previous reports of the effects of estrogens on other animals. The effect on nitrogen metabolism as observed in this experiment was somewhat greater than might be expected from reports in the literature.

Weight changes of the lambs during the experiment are given in table 3. Slow adjustment of the lambs to the experimental ration is believed to account for their small gain during the combined preliminary and collection periods of trial I. During trial II the rate of gain of the treated lambs was 68 percent over that of the control lambs.

There was an increase in the size of the mammary gland and teats of the stilbestrol-treated lambs. These lambs became nervous and restless about the third day after treatment, and continued in this state during the rest of the experiment.

Summary

Digestion trials which included calcium, phosphorus, and nitrogen balances were conducted with two groups of feeder lambs. One group was treated with 24 mg. of stilbestrol implanted in the neck region. The treatment had no apparent effect on the digestibility of major nutrients of the ration other than a slight increase in the digestibility of the crude fiber. There was a marked increase in the retention of calcium, phosphorus and nitrogen in the stilbestrol-treated lambs. Also, the stilbestrol-treated lambs gained weight at a considerably faster rate than the untreated lambs.

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THE ECONOMY AND NUTRITIVE VALUE OF DIFFERENT CUTS OF LAMB OF DIFFERENT GRADES [1]

JAMES D. KEMP,[2] SLEETER BULL and H. W. BEAN

University of Illinois [3]

A KNOWLEDGE of the economy and nutritive value of different cuts of meat of different species and grades is important for the consumer to select meat cuts wisely. Although there is considerable variation within grades due to the criteria used in grading or the individuality of the graders, carcass grades are still the most reliable guide for the average consumer to use in selecting meat for economy, nutritive value, and palatability. As the cost of meat is the largest single item in the total food cost for the average American family, this knowledge will help in planning meals and balancing the food budget.

Although the per capita consumption of lamb is much less than that of pork or beef, lamb is still in great demand in some sections of the country. The Western black-face lamb is the most important feeder and market lamb in this country; therefore, the composition of the different grades of this type of lamb will probably more nearly typify the average lamb than will any other breeds or crosses of lamb.

Although the work of Hankins and Foster (1940), Cover *et al.* (1944), and Wilford and Garrigus (1952) show that as the grades decrease there is a decrease in the percentages of fat and edible meat and an increase in the percentages of lean and bone, these data are not applicable to the present grading standards.

The work of Schweigert *et al.* (1949) and Greenwood *et al.* (1951) shows that the amino acid content of muscle protein is quite similar among species and among grades of the same species. The amino acids are also quite stable to proper cooking. Most meat proteins are highly digestible. Therefore, the protein content of meats is a good criterion of nutritive value.

Quantitative data regarding the composition of different grades of lamb have never been sufficient. On April 30, 1951, new U.S.D.A. grading standards became effective. Since that date few quantitative

[1] This paper is part of a thesis submitted by the senior author to the Graduate College, University of Illinois, in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Animal Science.

[2] Present address: Animal Husbandry Department, University of Kentucky, Lexington, Ky.

[3] Department of Animal Science.

data have been published regarding the new grades of lamb. The experiment reported in this paper presents some data on the physical and chemical composition of the carcasses and cuts of the different grades.

Experimental

Forty-five Western, range-type, black-face wether lambs ranging in weight from 70 to 119 pounds were slaughtered and produced 10 Prime, 13 Choice, 11 Good, and 11 Utility carcasses. The average shorn live weights for the respective grades were: Prime, 100 pounds; Choice, 92 pounds; Good, 88 pounds; and Utility, 79 pounds, with average respective carcass weights of 54.0, 46.4, 44.8, and 37.4 pounds. The average bone weights for the right sides were similar, being 3.7, 3.7, 3.9, and 3.9 pounds respectively, indicating that the lambs were of similar body structure.

After chilling in a 38° F. cooler for approximately 48 hours, the carcasses were weighed and graded. The grades were determined according to U.S.D.A. specifications (1951) by a committee of three graders. The carcasses were halved and cutting percentages were determined on the right half of each carcass using the method of cutting adopted by the 1952 Reciprocal Meats Conference. The cuts were weighed to the nearest .01 lb.

The cuts were separated mechanically into fat, lean, and bone and yellow connective tissue which was considered as bone. The fat and lean of each leg, loin, rack (rib), and shoulder were ground individually and samples were frozen for subsequent chemical analyses.

Determinations of moisture, dry matter, protein ($N \times 6.25$), and ether extract were made on the fat and lean of the four primary cuts. Moisture was determined by placing a sample in a vacuum oven at 75° C. for 24 hours, protein was determined by the macro-Kjeldahl method using mercury and potassium sulfate in the digestion mixture, and ether extract was determined by intermittent extraction for 24 hours with low petroleum ether. Physiological fuel values were calculated using the Atwater (1899) figures for meat protein and fat.

Methods of Calculation and Expression of Results

Dressing percentages were determined using shorn live weights and cold dressed weights. The weights of the cuts of the right side of each carcass were added to determine the weight of the side. This weight was used to determine the cutting percentages and the percentages of fat, lean, edible meat (fat + lean), and bone of each

carcass. The separable fat, lean, edible meat, and bone of each cut were expressed as percentages of that cut. The percentages of protein and ether extract were calculated on fresh and dry matter bases for fat, lean, and edible meat, and on the weight of the fresh cut. Physiological fuel values were expressed as Calories per 100 grams on the fresh and dry matter bases for fat, lean, and edible meat, and as Calories per 100 grams of fresh cut. Analysis of variance and "t" test were used to test the significance of the data.

TABLE 1. CUTTING PERCENTAGES

Grade	Leg	Loin	Rib	Shoulder	Breast and Flank	Fore-leg	Neck
			(Percentages)				
Prime	30.1	10.0	8.4	23.2	15.4	3.3	3.6
Choice	31.4	9.3	7.2	23.8	15.6	3.4	4.0
Good	31.5	9.3	7.4	24.6	14.1	3.6	4.2
Utility	31.3	9.0	7.4	24.5	13.7	4.2	4.5

Results and Discussion

The average dressing percentages of the lambs by grades were: Prime, 53.9; Choice, 50.5; Good, 50.7; and Utility, 47.1, the over-all difference being highly significant with no significant differences between Choice and Good.

Cutting Percentages

Table 1 shows the cutting percentages. The combined percentages of high priced cuts—leg, loin, and rib—do not change appreciably with carcass grade, although the percentage of leg tends to increase and the percentages of loin and rib tend to decrease with a decrease in grade, the over-all differences being significant with the greatest difference lying between Prime and other grades of rib. The percentage of shoulder generally increases with a decrease in grade. There are highly significant increases in the percentages of neck, foreleg, kidney, hind shank bone, and fore shank bone, and highly significant decreases in the percentages of breast and flank and kidney fat with a decrease in grade.

Physical Composition

The separable components of the carcasses and cuts are closely related to grade as shown in table 2. As the grade improves, the

percentages of fat and edible meat usually increase and the percentages of lean and bone decrease. These differences are highly significant among grades for fat, edible meat, and bone for the carcasses and all cuts, and for lean in all cuts except the foreleg and neck. There is a significant increase in lean in the neck with a decrease in grade, but no significant difference due to grade in the foreleg.

Chemical Composition and Physiological Fuel Values

The percentages of protein, ether extract, and dry matter, and the physiological fuel values of the primary cuts—leg, loin, rib,

TABLE 2. PHYSICAL COMPOSITION OF CARCASSES AND CUTS

Grade and Component	Carcass	Leg	Loin	Rib	Breast and Shoulder	Breast and Flank	Foreleg	Neck
	%	%	%	%	%	%	%	%
Prime								
Fat	33.2	23.6	36.9	41.9	28.1	47.6	21.4	28.4
Lean	50.8	62.4	51.9	43.7	57.5	41.2	50.9	50.8
Bone	14.0	12.8	10.0	12.9	12.1	8.4	27.1	20.1
Choice								
Fat	26.7	18.7	29.0	29.4	23.5	42.6	17.4	22.1
Lean	54.3	65.3	57.5	49.5	59.7	43.7	52.3	53.0
Bone	16.5	14.8	11.4	18.7	14.3	10.6	29.6	22.5
Good								
Fat	23.4	16.2	24.6	25.7	21.3	38.6	15.4	19.5
Lean	55.9	66.5	59.7	51.8	60.2	47.1	52.2	54.9
Bone	18.0	15.9	13.5	19.7	15.5	11.3	31.3	23.4
Utility								
Fat	19.7	14.2	19.3	21.3	19.1	33.1	13.4	16.4
Lean	56.5	66.6	61.1	52.0	60.8	49.8	52.6	53.3
Bone	21.5	18.0	18.0	24.8	18.2	14.1	33.1	28.8

and shoulder—and of the fat and lean of these cuts are shown in table 3.

Since most people eat meat for its protein, it is important to know where it is stored. There are no significant differences due to grade in the percentage of protein in the fresh lean of cuts. On the dry basis the lean of the lower grade cuts contains a higher percentage of protein, apparently due to the lower ether extract content. In general the average percentage of protein in the lean within a grade varies in the following order for the primary cuts: leg and loin, rib, and shoulder. The reason for this trend is probably due to the inaccuracy of physical separation. Due to the size and arrangement of muscles, the leg and loin can be separated more accurately and this accuracy decreases with rib and shoulder. As the grade improves, the percentage of protein in fresh and dry fat, fresh and dry edible

TABLE 3. CHEMICAL COMPOSITION AND PHYSIOLOGICAL FUEL VALUE OF THE PRIMARY CUTS AND THEIR PHYSICAL COMPONENTS

Grade and Component	Lean of Cut				Fat of Cut				Cut			
	Leg	Loin	Rib	Shoulder	Leg	Loin	Rib	Shoulder	Leg	Loin	Rib	Shoulder
Prime												
Protein %	19.8	20.0	19.3	18.8	5.8	4.8	3.9	5.1	13.7	12.2	10.0	12.2
Ether extract %	4.9	6.5	9.0	7.7	78.8	82.3	84.4	77.6	21.6	33.7	39.2	26.2
Dry matter %	26.5	28.2	29.8	28.0	84.5	87.0	88.2	83.0	....	....	....	....
Cal. per 100 gm.	128	142	160	152	733	762	776	720	254	355	396	290
Choice												
Protein %	20.0	20.0	19.4	18.3	7.0	6.5	5.9	6.2	14.7	13.3	11.5	12.4
Ether extract %	5.4	6.2	9.1	8.4	72.6	75.6	77.5	70.4	17.1	25.6	26.7	21.4
Dry matter %	26.9	27.8	29.9	28.2	80.1	82.4	83.6	77.0	....	....	....	....
Cal. per 100 gm.	136	142	165	153	688	708	724	659	217	292	294	246
Good												
Protein %	20.1	19.9	19.4	18.4	8.3	7.3	6.8	7.2	14.7	13.8	11.6	12.6
Ether extract %	4.8	5.8	7.8	7.6	68.0	73.2	75.8	64.4	14.2	21.7	23.8	18.4
Dry matter %	26.4	27.3	28.7	27.4	76.8	81.0	83.0	72.1	....	....	....	....
Cal. per 100 gm.	129	138	152	147	647	688	709	611	191	253	264	217
Utility												
Protein %	19.6	19.7	19.3	18.5	8.9	10.7	9.0	7.5	14.4	14.4	11.9	12.7
Ether extract %	4.0	4.8	6.8	6.2	65.9	61.5	67.5	64.2	12.1	14.8	17.6	16.2
Dry matter %	25.2	25.9	27.6	26.2	75.0	73.1	77.0	72.4	....	....	....	....
Cal. per 100 gm.	119	126	140	135	630	599	645	609	169	194	211	199

meat, and fresh cuts decreases, the differences being highly significant in all cases.

The percentage of dry matter in lean, fat, and edible meat decreases with a decrease in grade although there may be no difference in lean between some adjacent grades. The over-all differences are highly significant in all cases.

The ether extract content of the fresh and dry lean shows sig-

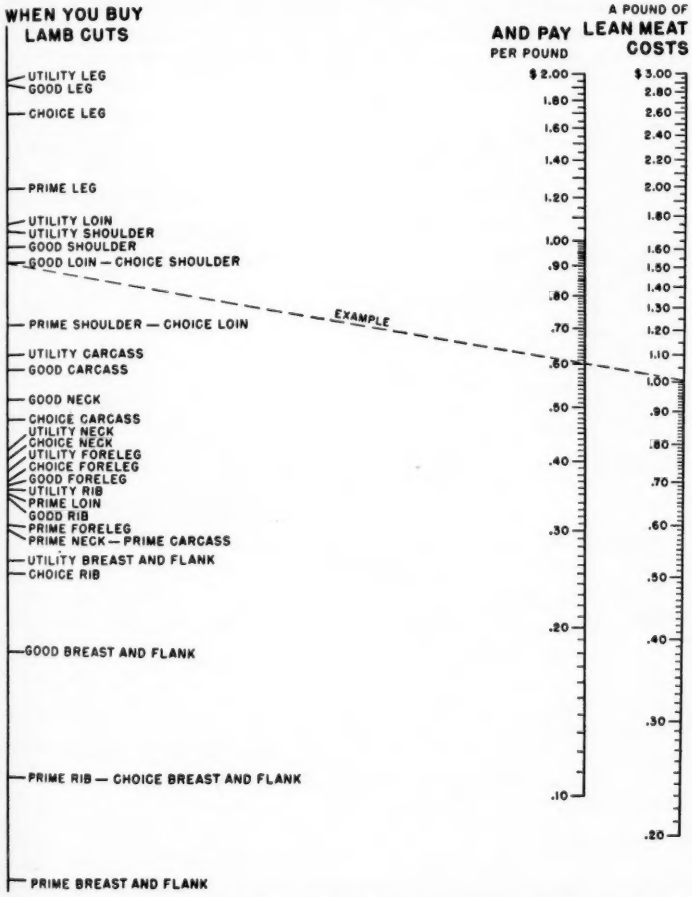

Figure 1. Cost per pound of lean in cuts and carcasses of different grades.

nificant or highly significant trends toward decreasing with a lowering of the grade. A few exceptions occur, especially between the Prime and Choice grades. The percentages of ether extract in fresh and dry fat, fresh and dry edible meat, and fresh cuts show highly significant decreases with decrease in grade. Physiological fuel values follow the same trend as ether extract.

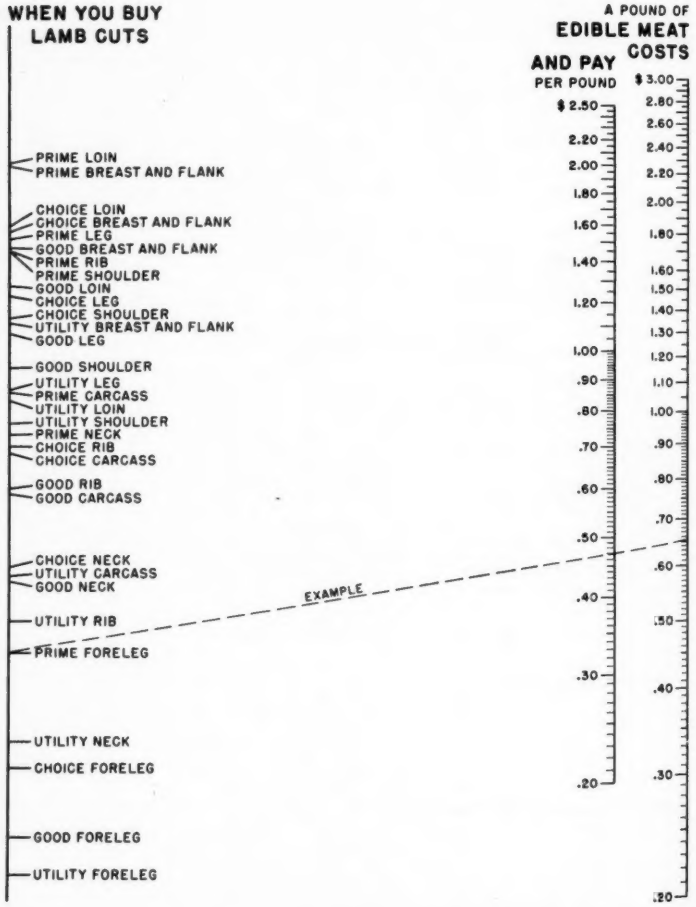

Figure 2. Cost per pound of edible meat in cuts and carcasses of different grades.

Economy

Figures 1 and 2 show the economy of cuts based respectively on the percentage of separable lean and edible meat for all cuts. Figure 3 shows the economy of cuts based upon the percentage of edible protein in the primary cuts.

Summary

Quantitative data were determined regarding the physical and chemical composition, energy values, and economy of the carcasses and retail cuts of 11 Prime, 13 Choice, 11 Good, and 11 Utility lamb

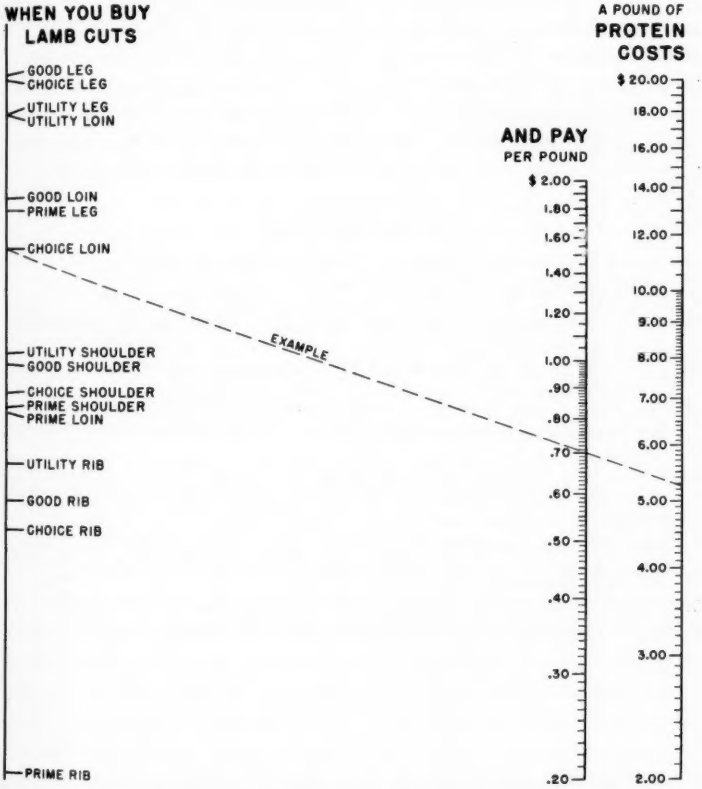

Figure 3. Cost per pound of protein in primary cuts of different grades.

carcasses from Western, black-face, wether lambs of similar breeding and size. The percentages of leg, shoulder, neck, foreleg, and kidney increase, but the dressing percentage, and the percentages of loin, rack, breast and flank, and kidney fat decrease with a decrease in grade. The percentages of edible meat and fat decrease, but the percentages of lean and bone increase, with a decrease in grade. Grade has no significant effect upon the percentage of protein in fresh lean; however, the percentage of protein increases with a decrease in grade in dry lean, fresh and dry fat, and fresh and dry edible meat. The percentage of ether extract decreases with a decrease in grade in fresh and dry fat, fresh and dry edible meat, and fresh cut but not always in fresh and dry lean. The percentage of dry matter in lean, fat, and edible meat decreases with a decrease in grade. Nomographic charts show the economy of cuts based upon the percentages of lean, protein, and edible meat. At the same price per pound of the same cut, lower grade cuts are more economical when purchased on a lean basis, similar in economy when purchased on a protein basis, and usually less economical when purchased on an edible meat basis.

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GAINS IN WEIGHT, NITROGEN RETENTION AND WOOL GROWTH OF LAMBS FED A RATION CONTAINING UREA SUPPLEMENTED WITH SODIUM SULFATE [1]

G. P. Lofgreen, W. C. Weir and J. F. Wilson

University of California [2]

IT has been demonstrated that inorganic sulfates can be used by rumen microorganisms to synthesize sulfur-containing amino acids (Loosli *et al.*, 1949; Block and Stekol, 1950; Block *et al.*, 1951; and Thomas *et al.*, 1951). This finding has stimulated considerable interest in the possibility of increasing the value of certain rations by the addition of inorganic sulfates. Natural feeds high in protein are usually good sources of sulfur; it is possible, however, that there may be a deficiency of sulfur in rations in which urea replaces these natural high-protein supplements and consequently one might expect that the addition of soluble sulfates would prove beneficial to such rations. The possibility also exists that sulfate present in natural feeds may not be as readily available as that from added inorganic sulfates. Loosli and Harris (1945) reported an increase in nitrogen retained by lambs when a urea ration was supplemented with sodium sulfate. Garrigus *et al.* (1950) found that elemental sulfur gave a marked response in wool growth when fed to lambs receiving a ration low in sulfur-containing amino acids. Willman *et al.* (1946) found, however, no beneficial effect by adding sodium sulfate to a urea ration, as measured by gain in weight. These rations, however, differed in their makeup and probably also in their total sulfur content.

The experiment described in this paper was designed to determine whether the addition of sodium sulfate to a ration made up mainly of natural feeds but containing urea would prove beneficial to growing-fattening lambs as measured by gains in body weight, nitrogen retention and wool growth. A further purpose was to determine whether the inorganic sulfur of the feeds used, as well as that of the added sulfate, would be readily available to the microorganisms of the rumen as measured by a comparison of the sulfur levels in the rations and in the rumen contents.

[1] This study was partially supported by a grant from the Dow Chemical Company, Midland, Michigan.

[2] Department of Animal Husbandry, Davis, California.

Experimental

Ten feeder lambs of mixed breeding and weighing approximately 60 pounds were divided at random into two groups. The five lambs in one group were fed individually a basal ration in which approximately 40 percent of the nitrogen was furnished by urea, and the five in the second group were fed individually the basal ration supplemented with 0.2 percent anhydrous sodium sulfate. This amount of sulfur in the form of methionine was found by Lofgreen *et al.* (1947) to

TABLE 1. INGREDIENTS OF RATIONS [1]

Ingredient	Ration	
	Basal	Basal Plus Sulfate
	Percent	Percent
Oat hay	40.00	40.00
Alfalfa meal	5.00	5.00
Barley, ground	21.90	21.90
Beet pulp, dried	10.00	10.00
Molasses, cane	10.00	10.00
Urea [2]	1.53	1.53
Sodium sulfate, anhydrous	....	0.20
Dicalcium phosphate	0.18	0.18
Oyster shell flour	0.26	0.26
Sodium chloride	0.55	0.55
Starch	5.29	5.19
Dextrose	5.29	5.19

[1] In addition to the above rations, a weekly supplement of vitamins A and D was given.
[2] The urea used was duPont "Two-Sixty-Two" and was kindly furnished by Marion N. Crady of the E. I. duPont de Nemours and Company, Wilmington, Delaware.

increase significantly the nitrogen retained by lambs fed a ration containing 40 percent of the nitrogen in the form of urea. The ingredients of the two rations are shown in table 1 and the chemical composition in table 2.

Calcium, phosphorus, total sulfur and the proximate principles were determined by the official methods of the A.O.A.C. (1950). The inorganic sulfate was determined by extracting 5 gm. of a finely ground sample with a 10 percent solution of trichloroacetic acid and filtering. The sulfur was precipitated from the filtrate with barium chloride and determined as in the case of total sulfur. That this method is reliable for determining inorganic sulfate in the added sulfur compounds is demonstrated by the values in table 2. The addition of 0.2 percent of sodium sulfate brought about an increase of 0.06 percent in the total sulfur and all of this increase occurred in the inorganic

fraction. As a further test of the method 0.2 percent of methionine was added to the basal ration. The total sulfur content was increased by 0.05 percent while the inorganic fraction as determined by the above method remained constant. Whether the inorganic sulfate in natural feeds is accurately determined by this method, however, is not certain.

Although it was attempted to feed all lambs at a level corresponding to 150 percent of their maintenance requirement (Brody *et al.*, 1934), they refused to consume this amount. They were therefore fed all the ration they would consume, which averaged 130 percent of their

TABLE 2. CHEMICAL COMPOSITION OF RATIONS, PERCENT ON DRY BASIS

Category of Interest	Ration	
	Basal	Basal Plus Sulfate
	Percent	Percent
Crude protein	13.4	13.4
Crude fiber	14.5	14.4
Ether extract	1.4	1.4
Ash	8.1	8.3
Nitrogen-free-extract	62.6	62.5
Calcium	0.59	0.55
Phosphorus	0.31	0.30
Total sulfur	0.23	0.29
Inorganic sulfur	0.15	0.21
Gm. N per gm. S	9.3	7.4

maintenance requirement during period 1 and 133 percent during period 2. At the end of the first 90-day period the dietary treatments of the two groups were reversed and feeding continued for a second 90-day period. Records were kept of the feed consumption of each lamb. Weekly measurements of body weight were made at the same time of day with reference to feeding, water being withheld for 12 hours prior to each weighing. As a further check on the adequacy of the sulfur levels in the ration, serum inorganic sulfate levels were determined on all lambs 37 days after the beginning of the first 90-day period.

Nitrogen balances were determined on representative lambs on each treatment as they reached 70, 80 and 90 pounds in body weight. Collection periods were 7 days in length after a preliminary period on a constant intake for at least 7 days. Collections were not continued beyond a weight of 90 pounds because of a limitation in the

size of the collection stalls. Since the lambs reached the 90-pound level early in the second 90-day period, the data from this weight are combined with those obtained during period 1 on the 70- and 80-pound levels. A total of nine collections were made on eight lambs being fed the basal ration and six collections on four lambs receiving the basal ration plus sodium sulfate.

At the beginning of each 90-day period, an area about 3 inches square near the point of the shoulder of each sheep was cleared of wool. For this purpose the Oster small animal clipper with a No. 2 head was used. The device shears almost at the surface of the skin. At the end of each 90-day period samples were collected by shearing

TABLE 3. THE EFFECT OF SULFATE AS A SUPPLEMENT TO THE BASAL RATION

	Ration			
Category of Interest	Basal	Basal Plus Sulfate	Basal Plus Sulfate	Basal
Lot number	1	2	1	2
Period number	1	1	2	2
Total gain per head, lb.	23.2 ±2.5[1]	21.1 ±1.4	21.8±3.8	19.8±2.4
Gain per 100 pounds of feed, lb.	11.6 ±1.2	10.8 ±0.4	8.8±1.0	8.3±0.7
Nitrogen balance:				
Nitrogen intake, gm. per day	22.8 ±1.0	22.4 ±1.5	.....	.....
Nitrogen retained:				
Per day, gm.	4.29±0.21	4.25±0.61	.....	.....
Percent of intake	18.8 ±0.2	19.0 ±1.9	.....	.....
Serum sulfate, mg. per 100 cc.	3.81±0.37	3.66±0.40	.....	.....
Length of wool staple, mm.	12.9 ±1.0	11.9 ±0.1	12.3±0.2	11.7±0.3

[1] Standard error of the mean.

this same area, thus insuring that the fibers represented the growth made during the preceding period. From the wool representing each period, several small sub-samples were made up. These were cleaned in benzene and ethyl alcohol and dried. They were then dyed by immersion and slight warming in a 5 percent aqueous solution of methyl violet acetified with acetic acid. The samples were pressed between layers of blotting paper and again dried. From the side of each sample 50 to 60 fibers were taken for measurement. It has been shown that since any sample of wool contains some fibers coarser than others, selection from the end of the bundle causes considerable bias. The operator will unconsciously choose the coarser ones because they are most visible and in so doing chooses the longest ones also. Selecting the fibers from the side of the bundle and taking them in sequence eliminates this bias. As each fiber was removed, it was placed

on a glass plate very lightly coated with egg albumen fixative. When all the fibers had been arranged in rows on the plate, a second piece of glass was placed over them and the edges secured with tape. The "slide" thus prepared was placed in a baloptician and the fiber images projected 20X against a hard wall covered with paper. Measurement for length was done with a cartographers map-measuring device which permits the operator to follow the fiber contour regardless of its crimp.

At the termination of the second 90-day period, the lambs were slaughtered from 3 to 5 hours after feeding and samples were taken of the rumen contents. The samples were stored frozen until the analyses could be made.

Results and Discussion

The gain in weight, efficiency of feed utilization, nitrogen retention, serum sulfate and the wool growth data are summarized in table 3. There were no significant differences in the results obtained on the basal ration and the basal supplemented with sulfate. The gain in weight, efficiency of feed utilization and wool growth were lower during the second 90-day period regardless of the treatment. The serum sulfate levels are well within the range found to be normal by Rendig and Weir (1952). The total sulfur content as well as the nitrogen to sulfur ratio of the basal ration indicates the sulfur level was well above that which results in low serum sulfate levels. The results indicate that apparently the sulfur present in the natural feedstuffs used in the rations was readily available and that the addition of a soluble sulfate did not improve the synthesis of protein from urea nitrogen. It is of importance to note that even though there was no high protein supplement in these rations and 40 percent of the nitrogen was furnished by urea there was still adequate sulfur in the ration.

The rumen contents taken from the lambs being fed the basal ration contained 14.7 percent protein on the dry basis and 0.14 percent total sulfur with only a trace of inorganic sulfur. The rumen contents from lambs fed the ration supplemented with sulfate contained 12.7 percent protein, 0.15 percent total sulfur and a trace of inorganic sulfur. Although it is possible that the inorganic sulfur could have been absorbed, it is also possible that the microorganisms have converted it to an organic form. If the latter were true, it would indicate that the inorganic sulfur in the natural feeds used in these rations was readily available to the rumen microorganisms.

The results of this study add evidence that the sulfur requirement for growing lambs is relatively small and that it is possible to meet

this requirement from natural feedstuffs without the addition of inorganic sources of sulfur. The possibility exists, however, that even though a response may not be obtained from a supplement of inorganic sulfur under a given set of conditions, there may be a response from an organic sulfur supplement such as that obtained by Loosli and Harris (1945) from methionine. Further work is needed to determine when a supplement of inorganic sulfur is and is not needed and under what conditions an organic source of surfur may prove necessary.

Summary

The addition of 0.2 percent sodium sulfate to a basal ration made up of approximately 87 percent natural feeds with urea furnishing 40 percent of the total nitrogen was without effect on gains in body weight, efficiency of feed utilization, nitrogen retention, serum sulfate levels or wool growth. The basal ration contained 0.23 percent total sulfur and 0.15 percent inorganic sulfur and had a nitrogen to sulfur ratio of 9.3 to 1.

Only a trace of inorganic sulfate could be detected in the rumen contents at 3 to 5 hours after feeding.

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SALT-COTTONSEED MEAL MIXTURE AS A SUPPLEMENT FOR BREEDING EWES ON THE RANGE

W. C. Weir and D. T. Torell

University of California

THE use of salt as a consumption-limiting agent in supplemental feed for sheep has been discussed by Weir and Miller (1952) in the report of a trial in which a limited number of ewes was fed a salt-cottonseed meal mixture under drylot conditions. In this paper results will be reported of a further trial conducted under actual range conditions.

Experimental

This test was conducted at the Hopland Field Station during the fall, winter and spring of 1951–52. The Hopland Field Station is located in southeastern Mendocino County, California. Formerly operated as a commercial sheep ranch, it was purchased by the University of California in July, 1951. It is primarily a hill ranch with some open grassland, considerable oak-woodland and some chamise brush cover. The major sources of forage are annual grasses and broadleaf plants. Some browse is obtained from the brush. The average annual rainfall is from 30 to 40 inches, but most of this occurs during the cold winter months. As a result, the green feed season is short and the feed is dry by late May or early June.

In this area sheep are run in large, fenced pastures without herding. On some of the more inaccessible ranches the sheep are only gathered once or twice a year, i.e., for shearing and marking the lambs. Progressive sheepmen have found, however, that supplemental feeding of the sheep during the fall and winter months is profitable in that the increased returns in lambs and wool more than pay for the cost of the supplemental feed.

Lambing occurs during the winter months of December, January and February so that the lambs will be able to take advantage of the spring green-feed season.

For this test 96 whiteface Merino-Romeldale type ewes purchased with the station were divided into two groups, weights and ages being equalized as far as possible. The two groups were rotated between two pastures. Pasture I of about 80 acres was fairly open woodland but had been heavily grazed before the test was started. Pasture II

of 210 acres had heavy tree and brush cover but carried more feed at the beginning of the test. Neither pasture was considered a good lambing pasture but these were the only fields available for this trial.

A mixture of 75 percent cottonseed meal and 25 percent granulated salt was provided free-choice from a covered self-feeder to the Group I ewes. The Group II ewes were hand-fed the amount of cottonseed meal the Group I ewes had consumed the previous two-week period. Water was available at all times and salt was provided free-choice to Group II.

The ewes were placed in the pastures on October 1. The forage supply was poor during the fall and winter as the fall rains were followed by weather too cold for feed to make much fall growth. By November the range feed was small in quantity and low in quality. Beginning on November 19, each group was supplemented with a small amount of alfalfa hay until March 1.

Lambing took place between December 10 and January 9. The ewes lambed in the pastures and received attention only when in trouble. The ewes were paint-branded with a number. As soon as possible after lambing, their lambs were caught and eartagged. Because of the brush it was not always possible to locate all of the lambs for a few days after birth. These lambs were not eartagged until all of the ewes were gathered and corralled when moved to the other pasture.

Heavy rains started in mid-November with 28.6 inches falling between November 12 and March 2. From December 24 to January 20, there were 14.7 inches of rain accompanied by some snow and freezing weather which was very hard on the young lambs.

By March 2 green feed was available, and the feeding of the hay and cottonseed meal supplements was terminated. The ewes were weighed individually on March 4 and turned out into a larger pasture with other sheep. On May 20 the sheep were gathered and the lambs weighed individually, weaned, and shipped for fattening on irrigated pastures. The ewes were turned back on the native pasture until June 6 when they were gathered again, shorn and weighed.

Results

The feed consumption of the two groups of ewes is shown in table 1. The daily consumption varied between 0.1 and 0.2 pound for the first 2 months. The lower consumption during the periods when Group I was in Pasture II is believed to be a reflection of the availability of better feed in that pasture. Feed consumption increased as pregnancy

progressed, as reported by Weir and Miller (1952), but in contrast to their findings, the largest consumption took place during the period immediately following lambing. The last ewe in Group I lambed on January 1 and the period of greatest salt-cottonseed meal consumption was from January 7 to 20. Feed was very short during this period

TABLE 1. FEED CONSUMPTION OF EWES
(Pounds per ewe daily)

	Group I, Self-fed				Group II, Control		
Period	Pasture	Cottonseed Meal	Salt	Alfalfa Hay	Pasture	Cottonseed Meal	Alfalfa Hay
October 1 October 14	I	0.119	0.040	....	II	0.200	....
October 15 October 28	II	0.092	0.031	....	I	0.120	....
October 29 November 11	I	0.168	0.056	....	II	0.090	....
November 12 November 25	II	0.118	0.039	0.90 [1]	I	0.168	0.90 [1]
November 26 December 9	I	0.182	0.061	0.98	II	0.118	1.00
December 10 December 23	II	0.239	0.080	0.95	I	0.169	1.00
December 24 January 6	II	0.273	0.091	0.93	I	0.216	1.22
January 7 January 20	I	0.347	0.116	1.50	II	0.286	1.41
January 20 February 3	I	0.198	0.066	1.04	II	0.346	1.04
February 4 February 17	II	0.100	0.033	0.52	I	0.184	0.52
February 18 March 2	I	0.073	0.024	1.04	II	0.100	1.04
Average for entire period		0.174	0.058	0.99 [1]		0.181	1.03 [1]

[1] Hay feeding started November 19.

and the weather was cold and wet. The greatest salt consumption per ewe daily was only 0.116 pound per day as compared to 0.231 pound found by Weir and Miller (1952). The availability of some green feed in February is believed to be reflected in the decreased supplement intake toward the end of the trial.

The ewe weights and wool weights are shown in table 2. There was no significant difference between the weights or between the gain or loss of the two groups during the trial. The weight loss up

to March 4 is partially due to lambing but also reflects a loss of condition by the ewes during this period. The weight gain from March 4 to June 6 is in addition to the wool weight as the ewes were weighed after shearing on June 6. Although the average gain was slightly larger for the control ewes, the self-fed ewes made a more uniform gain. This gain is believed to show that there were no serious after-effects from the prolonged high salt intake.

TABLE 2. EWE AND WOOL WEIGHTS

Group	I Self-fed			II Control		
Dates	Sept. 28	March 4	June 6	Sept. 28	March 4	June 6
Number of ewes	48	48	48	48	48	46
Av. wt. per ewe, lb.	118.1	84.4	95.8	114.4	82.5	96.0
Av. wt. loss, lb.	....	33.7	....	....	31.9	....
Standard deviation—wt. loss	....	8.3	....	....	8.5	....
Av. wt. gain, lb., March 4 to June 6	....	....	11.4	....	....	13.5
Standard deviation—wt. gain	....	....	5.1	....	....	8.2
Av. fleece weight, lb., June 6	....	....	6.5	....	....	6.6

The lamb data are given in table 3. The lamb losses were quite heavy in both groups, but not heavier than those experienced by many neighboring ranchers with sheep lambing at about the same time under range conditions. Most of the lambs which are shown as "unknown" are believed to have died in the brush from chilling during the worst of the storms. Despite the larger number of lambs weaned, the self-fed group produced lambs which averaged slightly more than the lambs produced by the control group. This difference in weaning weights is not significant.

Discussion

The results of this test under range conditions indicate that pregnant and lactating ewes may be safely fed a mixture of salt and cottonseed meal as a supplement to range feed if water is readily available at all times.

Franklin (1952) has reported that sheep fed drought rations once a week survived better than sheep hand-fed a small amount of supplemental feed each day. He believes that his results can be explained

on the basis that each of the sheep get a good fill at the weekly feeding and all starve for a few days, whereas on daily feeding, strong animals and rapid eaters get more than their share of the daily feed. He reports that some of the sheep fed daily gained weight and others in the same group died of starvation, while all of the sheep fed weekly lost about the same amount but very few died. An examination of the weight losses of the ewes in the salt experiment does not reveal

TABLE 3. LAMB DATA

Item	Group I Self-fed	Group II Control
Lambs born (known)	52	47
Dry ewes	5	5
Sets of twins born (known)	5	3
Sets of twins weaned	1	0
Lamb losses:		
Chilled	4	4
Stillbirths [1]	5	3
Dogs	0	3
Unknown	4	6
Accidents	0	1
Orphaned	0	1
Total	13	18
Lambs weaned	39	29
Lambing percentage (48 ewes)	81%	60%
Average weaning weight, lb.	72.1	68.6

[1] Includes unidentified lambs found in pastures. May include twins to lambs recorded as singles.

any difference in the weight loss or the weight loss variance between the two groups.

While the larger number of lambs weaned and the slightly larger weaning weight of the lambs of the self-fed group is interesting, it is not believed to be due to the difference in treatment of the two groups, but is believed to show that the large salt intake did not have any deleterious effect on the lamb crop.

From observations of the use of this method of feeding, the following advantages and disadvantages were noted:

Advantages:

1. Sheep do not need to be fed every day.
2. Each sheep has an opportunity to take as much supplement as it desires.

3. The sheep can increase its intake as the supply of other feed decreases.
4. Less feeder space is required. One foot of feeder space per three sheep is believed to be adequate.
5. All of the sheep do not have to be at the feeding grounds at feeding time to get their share of the supplemental feed.
6. Little feed is wasted as there is no crowding around the feeder.

Disadvantages:

1. The sheep may not be seen as often as is usually considered good management.
2. There is the additional cost of the salt and the cost of providing covered self-feeders.
3. Water must be plentiful.
4. Range sheep may need some training before they will eat from a self-feeder.

Further research is underway to determine the long-term effect of the large salt intake on the well-being of sheep.

Summary

A mixture of 25 percent salt and 75 percent cottonseed meal self-fed was compared with hand-fed cottonseed meal as a supplemental feed for pregnant and lactating ewes under range conditions. The supplement was fed from October 1 to March 2 to 48 range ewes. The average daily intake per ewe ranged from 0.073 pound cottonseed meal and 0.058 pound salt to 0.347 pound cottonseed meal and 0.116 pound salt. Lamb production, wool production and ewe weights gave no indication of adverse effects due to the large salt intake.

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THE ESTIMATION OF TOTAL DIGESTIBLE NUTRIENTS FROM DIGESTIBLE ORGANIC MATTER

G. P. LOFGREEN

University of California[1]

DIGESTION trials are usually conducted for the purpose of determining the coefficients of digestibility of each of the organic nutrients determined in the ordinary routine feed analysis. These coefficients are then used in the calculation of total digestible nutrients (TDN). Numerous objections to some of the determinations have been made with respect to their accuracy and their time-consuming nature. This is especially true in the determination of the carbohydrate fractions.

There are certain serious objections to the use of TDN as a measure of energy in evaluating feeds and in the feeding of livestock (Mitchell, 1942; Forbes *et al.*, 1943; Kleiber *et al.*, 1945; Morrison, 1948; and Maynard, 1951). TDN has, however, been adopted widely and is very useful in practical feeding operations and is suitable for many experimental purposes. Since the measurement of TDN in feeds and rations has become so important, it seems highly desirable that means of improving and simplifying its determination be investigated. If some method could be found which would make it possible to determine TDN from the digestibility of nutrients or classes of nutrients which can be more easily and accurately determined than those involved in the conventional method, it would be of great value to the research worker in determining the TDN content of various new feeds and in a number of other phases of experimental work. With this objective in view, a method was presented in an earlier report (Lofgreen, 1951) by which it is possible to determine the TDN content of feeds from the digestion coefficient for energy. In such a method it is necessary to determine moisture, ash and heats of combustion on the feeds and feces from a digestion trial and, in addition, ether extract on the feeds. Such a procedure is more accurate as a measure of the energy value of a feed than the conventional method of determining TDN, and overcomes some of the criticisms of the routine chemical analyses. There are, however, certain disadvantages of the method. A bomb calorimeter is necessary for the determination of heats of combustion

[1] Department of Animal Husbandry, Davis.

and all laboratories undoubtedly do not have this piece of equipment. A further disadvantage is that the full attention of the operator is required while the determination of heat of combustion is in progress. He is, therefore, unable to have other determinations in progress while using the bomb calorimeter. Because of these factors another method has been sought to determine TDN which would not depend upon the determination of separate digestion coefficients for the various classes of nutrients involved in the usual routine chemical analysis and would not involve the use of the bomb calorimeter.

In the method used to calculate TDN from digestible energy, the digestion coefficient for energy is multiplied by a factor, *F*, calculated by the following formula:

$$(1) \qquad F=\frac{OM}{100}\times\frac{100+(EE\times 2.25)-EE}{100}$$

where *OM* is the percent organic matter in the feed and *EE* is the percent ether extract in the organic matter (Lofgreen, 1951). Since the moisture and ash content of a feed is not involved in the determination of digestible energy, it is clear that the energy value of a feed or ration must be related to its organic matter content. If the various nutrients in the organic matter had the same digestibility, the heat of combustion of the feed and the feces would be the same per unit of organic matter, and the digestion coefficient of energy would thus be identical to that of organic matter. If this were the case, the digestion coefficient of organic matter could be converted to TDN by multiplying by *F* as calculated above. It appears, therefore, that there is a possibility of determining TDN from digestible organic matter provided the coefficients of digestibility of the various constituents of the organic matter are not radically different.

A consideration of the data on alfalfa hay compiled by Morrison (1948) makes it possible to compare the TDN determined by the conventional method with that which would theoretically be obtained from the digestible organic matter. A summary of the above data is presented in table 1. From these values it can be seen that there are 82.3 grams of total organic matter and 49.4 grams of digestible organic matter per 100 grams of hay. The digestibility of the organic matter is therefore 60 percent. Because of the differences in the digestibility of the various nutrients, the composition of the organic matter of the hay would be different from that of the feces. It can be calculated that the organic matter of the hay and feces would contain 18.0 and 13.1 percent protein, 2.4 and 4.3 percent fat, 35.1 and 49.2

percent fiber and 44.5 and 33.4 percent nitrogen-free-extract, respectively. If the average heats of combustion for protein, fat, fiber and NFE are assumed to be 5.65, 9.40, 4.25 and 4.15 kilocalories per gram respectively, the heat of combustion of the hay and feces per gram of organic matter would be 4.58 and 4.62 kilocalories respectively. Thus, even though the organic matter of the hay and feces appear to differ quite markedly, their heats of combustion are not far different. The digestion coefficient for energy therefore would not be far different from that for organic matter, and the TDN content of the hay could be estimated by applying F in formula 1 to the digestion coefficient for organic matter. F in the case of the data listed in table 1

TABLE 1. THE COMPOSITION AND DIGESTIBILITY OF ALFALFA HAY, ALL ANALYSES
(Morrison, 1948)

Category of Interest	Composition	Digestibility	Digestible Nutrients
	gm per 100 gm.	percent	gm. per 100 gm.
Protein	14.8	71	10.5
Fat	2.0	32	0.6
Fiber	28.9	44	12.7
Nitrogen-free-extract	36.6	70	25.6

would be 0.848 and the TDN would be 60×0.848 or 50.9 percent. The TDN determined by the conventional method is 50.3 percent. In using the digestible organic matter to determine TDN, it is assumed that both the fat and the non-fat organic matter are 60 percent digestible while actually the fat is 32 percent digestible and the non-fat organic matter is 61 percent digestible. If they had both been 60 percent digestible, there would have been 1.2 grams of digestible fat and 48.2 grams of digestible non-fat rather than 0.6 and 48.8 grams respectively, and the TDN by the conventional method would have been 50.9 rather than 50.3 percent. Thus, this rather large difference in the digestibility of the fat and of the non-fat organic matter results in a very small difference in the TDN, the difference being only 1 percent of the TDN content of the hay. Obviously, the difference in the two methods becomes larger as the difference in the digestibility of the fat and the non-fat organic matter increases, especially if the feed is high in fat.

Since in the majority of our common feeds fat makes up only a

small proportion of the organic matter, any difference in digestibility of the fat and the non-fat organic matter would result in only a small error in the estimation of TDN from digestible organic matter. It appears, therefore, that the possibility of estimating TDN from digestible organic matter is worthy of investigation because of the simplicity of the determination of organic matter in comparison to the usually determined organic nutrients. The method would consist of the following steps:

1. Conduct digestion trial on feed or feeds.
2. Determine moisture, ash and ether extract on feeds.
3. Determine moisture and ash on feces.
4. Calculate the digestibility of the organic matter.
5. Calculate the conversion factor, *F*, by a simplification of formula 1:

   (2) $$F = M(.01 + .000125\,E)$$

   where *M* is the percent organic matter in the feed and *E* is the percent ether extract in the organic matter.
6. Determine TDN by multiplying the digestibility of organic matter in percent by the conversion factor, *F*.

This paper presents the results of studies carried on to investigate the method proposed above for the determination of TDN from digestible organic matter and to compare the values obtained by this method with those obtained in the conventional manner.

Experimental

The TDN content of the feeds used in 50 digestion trials involving 13 feeds or feed combinations was determined by the conventional method. The conversion factor was calculated from the organic matter and ether extract content of each feed or feed combination according to formula 2. The factor thus calculated was applied to the digestion coefficients for organic matter obtained in the 50 trials to estimate the TDN content of the rations. The 23 trials involving five rations used previously to relate digestible energy to TDN (Lofgreen, 1951) were used in the present comparison. In addition 27 trials on eight rations were conducted using wethers and steers as the experimental animals, and have been used in the present study to relate digestible organic matter to TDN. All trials involved the feeding of the experimental ration at a constant level during a preliminary period of 7 to

10 days and a collection period of equal length. Chemical analyses were made according to the methods of the Association of Official Agricultural Chemists (1945).

Results and Discussion

A comparison of the TDN content of the 13 feeds and feed combinations as determined by the conventional method and as estimated from digestible organic matter is presented in table 2. The agreement

TABLE 2. A COMPARISON OF THE CONVENTIONAL AND ORGANIC MATTER METHODS FOR THE DETERMINATION OF TOTAL DIGESTIBLE NUTRIENTS

Ration	No. of Trials	Digestibility of Organic Matter	F	Total Digestible Nutrients: Organic Matter Method		Total Digestible Nutrients: Conventional Method	
		percent		percent		percent	
				mean	std. error	mean	std. error
Alfalfa hay, sample A	4	66.6	0.843	55.9	0.7	55.2	0.6
Alfalfa hay, sample B	4	59.2	0.826	48.9	1.7	48.1	1.7
Alfalfa hay; beet pulp, wet	4	71.3	0.234	16.7	0.1	16.3	0.1
Alfalfa hay; beet pulp, wet; molasses	4	72.2	0.212	15.3	0.02	15.0	0.1
Alfalfa hay, 75 percent; safflower meal, 25 percent	4	53.0	0.855	45.3	1.1	44.0	1.7
Alfalfa hay, 50 percent; safflower meal, 50 percent	4	47.5	0.884	42.0	1.6	41.7	1.7
Alfalfa hay, 25 percent; safflower meal, 75 percent	4	42.9	0.914	39.2	1.4	39.6	1.2
Oat hay; concentrate mixture A	7	66.5	0.838	55.7	0.7	55.6	0.7
Oat hay; concentrate mixture B	3	67.3	0.853	57.4	0.6	57.8	0.6
Oat hay; concentrate mixture C	3	66.9	0.851	56.9	1.4	57.4	1.2
Oat hay; concentrate mixture D	2	68.0	0.850	57.8	2.1	57.6	2.0
Oat hay; concentrate mixture E	3	68.3	0.857	58.5	0.9	58.5	0.8
Flax hulls	4	42.6	0.859	36.6	1.4	36.0	1.4

between the two sets of values is remarkable. As is indicated by the standard errors, the two methods have approximately the same variability which is to be expected since they are so closely related.

The results of the trials on alfalfa hay, sample B, are interesting in that the digestibility of the ether extract averaged only 4.6 percent in the four trials while the total organic matter had a digestibility of 59.2 percent. The large difference in the digestibility of the fat

and non-fat organic matter resulted in an estimated TDN content of 48.9 rather than 48.1 as determined by the conventional method.

These data demonstrate the validity of the estimation of the TDN content of feeds and feed combinations from digestible organic matter. The use of this method makes it possible to determine TDN with a minimum amount of chemical analyses, the necessary ones being moisture and ash on feeds and feces and ether extract on the feeds only. The time-consuming crude fiber determination is thus eliminated. Likewise it is unnecessary to determine heats of combustion as in the method involving digestible energy. It is obvious that the saving of time would be significant since moisture and ash are by far the simplest of all determinations used in feed analysis. The ether extract determination is also simple and need not be made on the feces since it is used only in the calculation of F. Although it is unnecessary to determine crude protein in the suggested method for the determination of TDN, it would often be desirable since values for digestible protein as well as for TDN are used in the balancing of rations for livestock.

The method previously described in which TDN is estimated from digestible energy is undoubtedly a more valid measure of the energy value of a feed than either the conventional or organic matter methods since it is based on actual energy determinations. The agreement, however, between the method based on digestible energy and the conventional method as demonstrated earlier (Lofgreen, 1951) and the close agreement between the conventional and organic matter methods makes it appear doubtful that there is any practical advantage of the use of the bomb calorimeter in the estimation of TDN under most conditions. The method based on digestible organic matter appears to be satisfactorily accurate and is unquestionably simpler than either of the other two methods.

Summary

A method is presented for the estimation of the total digestible nutrient (TDN) content of feeds from the digestibility of the organic matter.

The TDN values obtained in 50 digestion trials by the suggested method agreed very closely with those determined in the conventional manner.

The simplicity and time-saving features of the method are its important advantages.

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THE AVAILABILITY OF THE PHOSPHORUS IN ALFALFA HAY[1]

G. P. Lofgreen and Max Kleiber

University of California[2]

LITTLE is known concerning the availability of phosphorus in feedstuffs for ruminants. The recommended allowances of phosphorus of the various feeding standards are stated in terms of total phosphorus with no consideration being given to the availability of the phosphorus to the animal. It is reasonable to expect that the availability of the phosphorus may differ in various feeds and in the same feed at different stages of maturity. The lack of information is understandable since the main pathway for the excretion of phosphorus in ruminants is by way of the feces (Forbes *et al.*, 1922), and the feces therefore contain phosphorus which is excreted from the body (metabolic phosphorus) as well as undigested phosphorus from the feed. It has been difficult to determine the amount of phosphorus originating from these two sources and therefore has been impossible to determine what proportion of the phosphorus of a feed or ration is unavailable to the animal. The method of determining metabolic phosphorus in the feces by measuring the fecal phosphorus excretion while feeding a phosphorus-free ration or while the animal is fasting is open to considerable criticism. It is difficult to compound a ration free of phosphorus which would be readily consumed by the animal. Animals subjected to such treatments cannot be considered to be under normal conditions, and there is some doubt that the phosphorus excretion obtained under these conditions is a good measure of the metabolic phosphorus excreted during phosphorus feeding. These various factors have prevented the accumulation of knowledge concerning the availability of phosphorus in specific feeds.

By the use of isotopes of phosphorus it is possible to determine the metabolic phosphorus excretion of an animal. If the body phosphorus of an animal were labeled with an isotope of phosphorus, it would be possible to determine the proportion of the fecal phosphorus which was originating from the body since that fraction would be labeled while that passing through the gastrointestinal tract would not be labeled. This latter fraction would represent that which was

[1] This study was partially supported by a grant from the U. S. Atomic Energy Commission.

[2] Department of Animal Husbandry, Davis.

unavailable for digestion and absorption. A second possibility for the use of isotopic phosphorus would be to label the phosphorus in the feed rather than the body phosphorus. Kleiber *et al.* (1951) have used the former method with dairy cows while Lofgreen *et al.* (1952) have used a combination of both methods with calves.

The work of Hevesy (1948) and of Kleiber *et al.* (1951) indicates that when the body phosphorus is labeled by the injection of radioactive phosphorus, P^{32}, the phosphorus secreted into the gastrointestinal tract has the same specific activity as the inorganic phosphorus of the blood plasma. Kleiber *et al.* (1951) found that in the cow the maximum amount of P^{32} appeared in the feces 2 days after the injection of P^{32} into the blood stream. It was therefore assumed that the amount of P^{32} excreted into the intestinal tract during 1 day would be excreted in the feces 2 days later.

In lambs it has been noted in earlier trials that the maximum specific activity (microcuries P^{32} per gram of phosphorus) is reached in the feces 24 hours after the injection of P^{32} into the blood stream. Following the same line of reasoning as outlined above, it may be assumed that the P^{32} excreted into the intestinal tract during a given time will appear in the feces about 24 hours later. If the inorganic phosphorus of the blood plasma (trichloroacetic acid filtrate) is labeled by the injection of P^{32}, the proportion of the fecal phosphorus which is of metabolic origin can theoretically be determined as outlined in figure 1. It is obvious from figure 1 that the relationship between the plasma inorganic phosphorus and the fecal phosphorus can be formulated

$$\pi_{(t)}\, M = \phi_{(t+24)} \qquad (1)$$

where $\pi_{(t)}$ is the specific activity of the plasma inorganic phosphorus (plasma TCF) at time $_t$, $\phi_{(t+24)}$ is the specific activity of the feces 24 hours later, and M is the proportion of the fecal phosphorus which originates from the plasma inorganic phosphorus and thus represents the metabolic fraction. Equation 1 can be rewritten

$$M = \frac{\phi_{(t+24)}}{\pi_{(t)}}. \qquad (2)$$

Consequently the ratio of the fecal specific activity to the plasma inorganic phosphorus specific activity 24 hours earlier represents the proportion of the fecal phosphorus which is of metabolic origin. Since π and ϕ can be measured, it is possible to determine M. The proportion of the fecal phosphorus which originates from the feed and passes through the tract undigested is equal to 1—M. If the daily

phosphorus intake and the daily fecal phosphorus excretion are known, it is then possible to calculate the true digestibility of the phosphorus in the feed. The use of this method provides an opportunity to study the availability of the phosphorus in various feeds and rations which heretofore have not been studied.

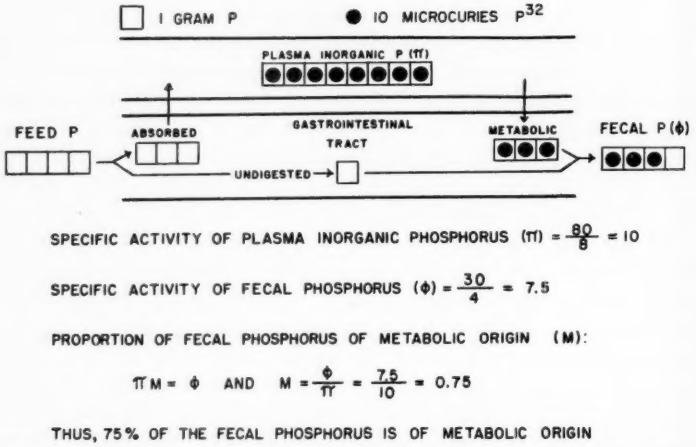
1 GRAM P
10 MICROCURIES P^{32}
PLASMA INORGANIC P (π)
FEED P
ABSORBED
GASTROINTESTINAL TRACT
METABOLIC
FECAL P (φ)
UNDIGESTED
SPECIFIC ACTIVITY OF PLASMA INORGANIC PHOSPHORUS (π) = $\frac{80}{8}$ = 10
SPECIFIC ACTIVITY OF FECAL PHOSPHORUS (φ) = $\frac{30}{4}$ = 7.5
PROPORTION OF FECAL PHOSPHORUS OF METABOLIC ORIGIN (M):
$\pi M = \phi$ AND $M = \frac{\phi}{\pi} = \frac{7.5}{10} = 0.75$
THUS, 75% OF THE FECAL PHOSPHORUS IS OF METABOLIC ORIGIN

Figure 1. Method for determining the proportion of the fecal phosphorus which is of metabolic origin.

Since alfalfa hay is one of the most commonly used roughages, an experiment was set up to study the availability of the phosphorus in this important feedstuff.

Experimental

Five wether lambs weighing between 68 and 80 pounds were fed chopped No. 2 alfalfa hay at a constant level for a period of from 10 to 12 days. On the evening of the seventh day they were placed in metabolism stalls equipped to collect urine and feces separately. Beginning on the morning of the eighth day, each lamb was injected four times daily at 6 a.m., 12 noon, 6 p.m. and 12 midnight with 150 microcuries P^{32} in an isotonic solution of sodium phosphate.

Four of the lambs were given 14 such injections and one was given 13 injections. The entire fecal excretion of each lamb was collected twice daily at 8 a.m. and 8 p.m. Each 12-hour sample was dried, ground and analyzed separately.

In order that the specific activity of the blood might be determined 24 hours prior to the period during which a fecal sample was taken, blood samples were drawn at 11 a.m. and 5 p.m. each day. The average specific activity of these two samples was assumed to be representative of the average specific activity of the blood from 8 a.m. to 8 p.m., and thus could be used together with the fecal sample taken from 8 a.m. to 8 p.m., 24 hours later, to calculate M in equation 2. These two blood samples would not, however, be representative of the blood over the 24-hour period during which they were taken.

Total phosphorus was determined in all samples by wet ashing with sulfuric and nitric acids and determining the phosphorus colorimetrically as molybdivanado-phosphoric acid (Koenig and Johnson, 1942; Kitson and Mellon, 1944). The P^{32} content of the samples was measured by the method described in detail by Kleiber *et al.* (1951).

Because of the nature of the experiment some difficulty was encountered in keeping the lambs on a constant intake of hay after the beginning of the injections and drawing of blood samples. Constant intakes were maintained, however, from 3 to 5 days after the beginning of the injections. The fecal samples collected during these periods on a constant intake were used to determine the phosphorus availability of the hay.

The information relative to the treatment of the experimental animals is summarized in table 1.

Results and Discussion

The average ratios of the specific activity of the feces to that of the plasma inorganic phopshorus 24 hours earlier (M in equation 2) for the five lambs were 0.95 ± 0.07, 0.93 ± 0.11, 0.75 ± 0.05, 0.84 ± 0.06 and 0.93 ± 0.06. These values represent the proportion of the fecal phosphorus which is of metabolic origin, the remainder being undigested feed phosphorus. Thus, in the feces of these five lambs being fed alfalfa hay, an average of approximately 88 percent of the phosphorus was of metabolic origin and 12 percent was phosphorus which was unavailable for absorption by the animals.

In table 2 are presented the individual data of each lamb showing the division of fecal phosphorus into metabolic and undigested fractions and the apparent and true digestibility of the phosphorus. The average apparent digestibility of the phosphorus was 22 percent while the true digestibility averaged 91 percent. It is interesting to note

TABLE 1. TREATMENT OF THE EXPERIMENTAL ANIMALS

Lamb No.	Body Weight	No. of Injections of P^{32} Solution	Total P^{32} Administered	Time on Collection	Daily Intake of Alfalfa Dry Matter
	lb.		microcuries	days	grams
1	68	14	2100	4	906
2	73	13	1950	3	906
3	79	14	2100	4	978
4	80	14	2100	4	978
5	68	14	2100	5	906

that lambs 3 and 4, being slightly larger than the others, received 72 grams more dry matter per day than lambs 1, 2 and 5, and the true digestibility of the phosphorus fed to these was lower than that of the phosphorus fed to the three smaller lambs. Whether this difference is due to differences in individual animals or whether it indicates an effect of intake upon true digestibility of phosphorus is not known. It is also interesting that lamb 5, while showing the lowest apparent digestion of the phopshorus of alfalfa, actually absorbed 94 percent.

The true digestibility values obtained in this experiment show a high percentage of the phosphorus in the alfalfa hay used was available for absorption. Kleiber *et al.* (1951) reported that the phosphorus in a ration consisting of equal parts alfalfa hay and a mixed concentrate, when fed to two lactating dairy cows, had a true digestibility of 50 and 64 percent. If the phosphorus in the alfalfa hay used in

TABLE 2. THE AVAILABILITY OF THE PHOSPHORUS IN ALFALFA HAY

Category of Interest	Lamb No.				
	1	2	3	4	5
Daily P intake, gm.	2.31	2.31	2.49	2.49	2.31
Daily fecal P excreted, gm.	1.78	1.69	1.88	1.96	1.98
Proportion of fecal P of metabolic origin, %	95	93	75	84	93
Proportion of fecal P undigested, %	5	7	25	16	7
Daily metabolic fecal P excretion, gm.	1.69	1.57	1.41	1.65	1.85
Daily undigested fecal P excretion, gm.	0.09	0.12	0.47	0.31	0.14
P apparently digested, gm.	0.53	0.62	0.61	0.53	0.32
Apparently digestibility of P, %	23	27	24	21	14
P truly digested, gm.	2.22	2.19	2.02	2.18	2.17
True digestibility of phosphorus, %	96	95	81	88	94

their study was as available as that reported in this paper, the availability of the phosphorus in the concentrate mixture must have been rather low. This raises again the interesting question as to the comparative availability of the phosphorus in roughages and concentrates for ruminants. This problem can now be studied further.

Further work is necessary to determine the availability of phosphorus under various conditions, such as at varied levels of calcium, at different stages of plant maturity and with high- and low-phosphorus feeds. Williams *et al.* (1940) found that the phosphorus in a high-phosphorus alfalfa hay was more available to rats for growth and bone development than that of low-phosphorus hay. It would be interesting and of value to know if this were also true with ruminants.

Summary

A study is described in which the true digestibility of the phosphorus in alfalfa hay is determined using five lambs as experimental animals.

It was found that an average of 88 percent of the fecal phosphorus of lambs fed alfalfa hay was of metabolic origin and 12 percent was undigested phosphorus from the hay.

While the apparent digestibility of the phosphorus of the hay averaged 22 percent, the true digestibility was 91 percent, indicating that the phosphorus in the alfalfa hay used in this study was highly available for absorption by lambs.

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EFFECT OF PHOSPHORUS DEFICIENCY ON METABOLISM OF CAROTENE AND VITAMIN A BY BEEF COWS

O. O. Thomas,[1] Willis D. Gallup and C. K. Whitehair [2]

Oklahoma Agricultural Experiment Station [3]

THE metabolism of carotene and vitamin A in domestic animals has been shown to be influenced by several compounds. Reference to investigations of the importance of these compounds has been made in a previous publication (Gallup *et al.*, 1951) dealing with protein supplements and urea.

The possibility that phosphorus affects the utilization of carotene was suggested by an observed inverse relationship between the inorganic phosphorus and carotene content of the blood plasma of Hereford cows maintained on adequate- and low-phosphorus rations (Ross and Gallup, 1949). This inverse relationship was also apparent in Hereford steers fed adequate- and low-phosphorus rations and known amounts of carotene (Thomas, Gallup and Ross, 1951). Although inefficient conversion of carotene to vitamin A was indicated in the results with steers, supporting evidence was not obtained in similar studies conducted with lambs (Thomas, 1951); vitamin A levels in the blood and liver of lambs fed nine times their minimum requirement of carotene were unaffected by phosphorus deficiency. Further work, as reported in the present paper, was therefore initiated with beef cows. The development of a biopsy technique (Van Arsdell, Whitehair and MacVicar, 1951) has made it possible in this latter work to secure liver samples for carotene and vitamin A determinations at regular intervals during the experimental period.

Procedure

Nine bred grade Hereford cows averaging 11 years of age were used in this study. They were grazed during the summer and fall of 1950 on native grass supplemented with a mineral mixture consisting of three parts bonemeal and one part salt. On November 16, 1950, the cows were placed in dry-lot and fed a low-phosphorus ration composed of 1.5 lb. corn gluten meal with prairie hay, free choice. The

[1] Present address, Montana State College, Bozeman, Montana.
[2] Present address, University of Illinois, Urbana, Illinois.
[3] Departments of Animal Husbandry and Agricultural Chemistry Research.

ration provided an average daily intake of about 0.6 gm. of phosphorus per 100 lb. liveweight and 113 mg. of carotene. Blood samples were taken by venous puncture at regular intervals, and at the end of 71 days, which was estimated to be about 4 to 8 weeks before parturition, liver samples were obtained by biopsy technique (VanArsdell *et al.*, 1951). The blood plasma was analyzed for carotene and vitamin A (Kimball, 1939) and inorganic phosphorus (Fiske and Subbarow, 1925). Liver samples were analyzed for carotene and vitamin A (Gallup and Hoefer, 1946). The results of these analyses were used as a guide in dividing the cows into two comparable lots. From this time until the end of the experiment, four cows making up Lot 1 were continued on the phosphorus-deficient ration, and five cows as Lot 2 were fed the same ration supplemented with sufficient bonemeal to provide an intake of approximately 3 gm. of phosphorus per 100 lb. liveweight. Calcium carbonate was used to equalize calcium intake. The carotene content of the ration was adjusted during the experiment at the desired level by substitution of beet pulp and cottonseed hulls for part of the prairie hay. Carotene intakes were kept relatively high during the first part of the experiment and low during the last part.

At the time of calving, the cows were placed in individual pens so that carotene and phosphorus intakes could be individually controlled. Blood, liver and colostrum samples were obtained from each cow at parturition. Thereafter blood samples were taken at weekly intervals for 4 weeks, and at the 6th, 8th, 12th, 16th, and 20th week of lactation; milk samples were taken at the same time up to and including the 8th week; liver samples were taken at the 4th, 8th, 16th, and 20th week of lactation. Milk samples were kept frozen until analyzed for carotene and vitamin A (Boyer *et al.*, 1944). Liver samples were wrapped in cellophane and frozen until analysis could be made the following day.

Although it was originally planned to discontinue the experiment at the 8th week of lactation, two cows in each lot calved at an earlier date than the others, making it possible to extend the observations with these four cows through the 12th week. The results were of sufficient interest that observations were continued beyond the 12th week to 20 weeks. From the 12th to the 20th week, the ration for these four cows was made extremely low in carotene by complete replacement of prairie hay with beet pulp.

Results and Discussion

The pertinent data from these studies are summarized in table 1 showing the carotene and vitamin A content of the blood plasma, liver and milk of the cows in relation to phosphorus intake and phosphorus levels in the blood.

The cows in the high-phosphorus lot required no assistance at the time of calving, and all calves appeared to be strong. In the low-phosphorus lot one cow required assistance at calving, and another lost her calf at calving time. The latter cow was given a Holstein calf to suckle. All calves in the low-phosphorus lot were weak at birth.

At the time the cows were divided into two lots and phosphorus supplementation started for Lot 2, the average plasma-inorganic phosphorus level of both lots was 2.8 mg. per 100 ml. of plasma. At parturition, the average was 4.0 mg. for the low-phosphorus lot and 7.9 mg. for the high-phosphorus lot. Eight weeks after parturition, these values were 2.6 and 5.6 mg., and at 20 weeks, 2.8 and 4.2 mg., respectively. It is evident, therefore, that plasma phosphorus in cows of Lot 1 was being kept at a low level by the low-phosphorus intake.

Plasma Carotene and Vitamin A

Initially, the cows of Lot 1 and Lot 2 had similar plasma carotene values of 194 and 190 mcg. per 100 ml., respectively. Differences in these values became greater as the experiment progressed to 6 weeks after calving. At parturition, plasma carotene was 180 mcg. per 100 ml. in the cows of Lot 1 and 165 in those of Lot 2. During the first 4 weeks after calving, the average values were 158 for Lot 1 and 138 for Lot 2; this difference approached statistical significance. During the next four-week period, when carotene intake was greatly reduced for both lots, consistent but small differences in plasma carotene between lots were still apparent. Although carotene values at each bleeding date from the time of phosphorus supplementation until 8 weeks after parturition were higher for the cows of Lot 1 than for those of Lot 2, these differences were never greater than 31 mcg. In view of the wide range of carotene values associated with normal performance of beef cows (Long *et al.*, 1952) differences of this magnitude, despite their reality, are not usually regarded as having physiological importance. Carotene values for the two cows in each lot which received 40 mg. of carotene per day during the 8 to 12 week period after calving, and only 11 mg. thereafter, decreased

TABLE 1. CAROTENE AND VITAMIN A CONTENT OF PLASMA, LIVER AND MILK OF BEEF COWS ON LOW- AND ADEQUATE-PHOSPHORUS RATIONS [1]

Lot No. and Phosphorus Level		Number of Cows	Phosphorus Intake,[2] Daily gm./100 lb., Live Weight	Carotene Intake [2] Daily mg.	Plasma Inorganic Phosphorus mg./100 ml.	Plasma		Liver		Milk	
						Carotene mcg./100 ml.	Vitamin A mcg./100 ml.	Carotene mcg./gm.	Vitamin A mcg./gm.	Carotene mcg./100 ml.	Vitamin A mcg./100 ml.
Initial (at time of allotment for phosphorus supplementation)											
1	Low	4	0.62	113	2.8	194	8.9	11.9	273.1	.....	.....
2	High	5	0.62	113	2.8	190	9.9	10.1	197.4	.....	.....
Parturition											
1	Low	4	0.60	91	4.0	180	9.2	9.7	260.8	126.7	195.1
2	High	5	3.25	85	7.9	165	9.3	8.5	161.4	169.1(89.8)[3]	276.0
First 4 weeks postpartum											
1	Low	4	0.71	116	3.0	158	7.5	9.4	276.3	4.9**	6.3
2	High	5	3.38	116	6.6	138	7.4	7.5	155.3	3.4	7.4
4–8 weeks postpartum											
1	Low	4	0.86	36	2.6	129	12.7	6.3	173.4	3.4	3.0
2	High	5	3.25	38	5.6	126	12.9	6.8	132.7	1.4	5.4
8–12 weeks postpartum											
1	Low	2	1.00	40	3.8	49	16.0	3.9	77.5	.....	.....
2	High	2	3.77	40	4.4	82	22.4	2.3	21.9	.....	.....
12–20 weeks postpartum											
1	Low	2	0.73	11	2.8	34	25.3	3.1	71.7	.....	.....
2	High	2	3.72	11	4.2	27	21.4	1.6	22.7	.....	.....

** Significant at 1% level over Lot 2.

[1] Average of individual values. Samples of blood and milk were collected at parturition, each week for 4 weeks post-partum and at the 6th and 8th week of the 4–8 weeks period. Blood was collected at the 12th week of the 8–12 weeks period and at the 16th and 20th week of the 12–20 weeks period. Liver samples were taken at the end of each period.

[2] Phosphorus and carotene intake values are for 71 days preceding allotment, 56 days preceding parturition and for the number of weeks indicated in each subsequent period.

[3] Average with one erratic value of 486 mcg. omitted.

markedly in a manner that was unrelated to phosphorus intake or plasma phosphorus levels.

The average initial vitamin A content of the plasma of cows of Lots 1 and 2 was 8.9 and 9.9 mcg. per 100 ml., respectively. At the time of parturition, the values for both lots were slightly over 9 mcg., but during the 4 weeks thereafter they dropped to about 7.5 mcg. Despite a lowered carotene intake in the next four-week period, plasma vitamin A increased to over 12 mcg. Further, the vitamin A content of the plasma of the two cows in each lot that were continued on experiment increased markedly and reached maximum average values of 25.2 mcg. for Lot 1 and 31.2 for Lot 2 at 16 weeks; at 20 weeks these values were 25.3 and 21.4, respectively. During the latter period, the cows received only 11 mg. of carotene per day. The only indication that these increases resulted from mobilization of tissue reserves during the last stages of vitamin depletion is contained in the results of the liver analysis and in the observation of typical deficiency symptoms (night blindness and muscular incoordination) in one of the cows of Lot 2 after the 16th week. With respect to phosporus intake and plasma vitamin A levels, the results reveal no definite relationship or trend.

Liver Carotene and Vitamin A

The initial amount of carotene in the liver was about 18 percent higher in the cows of Lot 1 than in those of Lot 2. Liver carotene values decreased in both lots at parturition and during the 4 weeks thereafter. These decreases, which amounted to 2.5 and 2.6 mcg. per gram, were only slightly less for the low-phosphorus lot than for the high-phosphorus lot, on a percentage basis. An abnormally high value of 10.2 mcg. was obtained with one cow in the high-phosphorus lot at the end of the 4 to 8 week period after calving. At 16 weeks the two cows that were continued on experiment in each lot had lost 66 percent of the carotene present in the liver previous to parturition; at the end of 20 weeks about 75 percent had disappeared. These changes were unrelated to phosphorus intake.

Of particular interest are the liver vitamin A values which in the low-phosphorus lot stayed above 260 mcg. per gm. through parturition and for 4 weeks thereafter, but decreased in the high-phosphorus lot from 197.4 to 155.3 mcg. during the same period of relatively high carotene intake. These unexpected results lend no support to the idea that phosphorus deficiency may adversely affect the conversion of carotene to vitamin A and its storage in the liver. They may indicate,

however, that phosphorus deficiency slows down the mobilization of vitamin A from liver stores and its transfer to milk during early lactation. At 8 weeks after calving, the cows in both lots had lost about an equal amount, 34 percent, of their initial liver stores of vitamin A. The low carotene intake during this period and the subsequent periods resulted in a further loss, and by the 20th week the two cows in Lots 1 and 2 had lost 69 percent and 83 percent of their initial liver vitamin A, respectively.

Milk Carotene and Vitamin A

Colostrum from one of the cows of Lot 2 contained over four times the amount of carotene found in any of the other samples. With this one value of 486 mcg. omitted from the average, there was a definite trend for both the milk and colostrum from the cows on the low-phosphorus ration to be higher in carotene, but lower in vitamin A, than that from the cows fed adequate phosphorus. Differences in carotene of milk between the low- and high-phosphorus lots were highly significant (Snedecor, 1946) 4 weeks after calving and closely approached significance during the 4 to 8 week period. Differences in vitamin A of milk approached significance only during the 4 to 8 week period. Further work with dairy cattle seems warranted.

Summary

Nine bred Hereford cows, after a preliminary period of low-phosphorus intake, were used to study the effect of phosphorus deficiency on carotene metabolism. For an average period of 8 weeks before calving and 8 weeks or longer thereafter, four of the cows were continued on the low-phosphorus ration and five were given a phosphorus supplement. All of the cows received equal but limited amounts of carotene supplied by prairie hay. Determinations were made of the phosphorus content of the plasma and the carotene and vitamin A content of the plasma, liver, and milk of the cows at regular intervals.

Average plasma-carotene levels were generally higher in the phosphorus-deficient cows than in those fed adequate phosphorus; these differences approached statistical significance (5% level). Plasma-vitamin A levels appeared to be unaffected by phosphorus deficiency. At 8 weeks after calving both groups of cows had lost similar amounts of carotene and vitamin A from the liver. Milk from the phosphorus-deficient cows contained more carotene but less vitamin A than that from the cows fed adequate phosphorus.

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THE EFFECT OF SELF-FEEDING SALT-COTTONSEED MEAL MIXTURES TO BEEF COWS

J. K. Riggs, R. W. Colby and L. V. Sells [1, 2]

Texas Agricultural Experiment Station

SELF-FEEDING mixtures of salt and cottonseed meal to range sheep probably began in Texas along the Pecos River about 1934. At first the practice grew slowly. Probably shortage of labor during World War II had more influence in stimulating self-feeding of salt mixtures to limit intake of cottonseed meal than any other one factor. The practice evidently met with enough success among both sheepmen and cattlemen to be continued after the wartime labor shortage was relieved, because today it appears to be more popular than ever before.

The advisability of self-feeding salt-concentrate mixtures has been widely debated. The success of such a practice hinges on whether high salt intake over a considerable period of time is detrimental to the kidneys, the reproductive function or the digestion of nutrients. Some work has been done with steers and with sheep, but little has been reported with beef breeding cows. This experiment was designed at the request of Central Texas cattlemen to develop information regarding the reaction of cows to high salt intake.

A daily intake of 0.033 to 0.066 pound of salt, depending upon stage of development of the forage, has been recommended for range cattle by Jardine and Anderson (1922).

Stanley (1949) suggested that our usual conception of salt requirement for cattle and sheep is not necessarily correct. He reported heavy salt consumption to have significantly increased the digestion of the cellulose of alfalfa hay by one cow on test at the Arizona station.

Pickett and Smith (1949) reported that two-year-old steers hand-fed 3 pounds of cottonseed cake per head daily on bluestem pasture gained 0.43 pound more per day on 0.54 pounds less cottonseed cake than similar steers self-fed a mixture composed of 30 pounds of salt and 100 pounds of cottonseed meal. The daily salt intake of the self-fed steers was slightly over 1 pound per head during the grazing

[1] Departments of Animal Husbandry and Biochemistry and Nutrition.

[2] The authors wish to express their appreciation to Mr. J. G. Moffett of the Department of Animal Husbandry, to Dr. Hilton A. Smith, head of the Department of Veterinary Pathology, and to Dr. R. D. Turk, head of the Department of Veterinary Parasitology for their cooperation in this work.

period, and although the hair on these steers was rough and they were not as fleshy as those hand-fed cottonseed cake, both groups made practically the same gain during a subsequent finishing period. In further work by the same authors, yearling steers wintered on Kansas bluestem pasture and a self-fed mixture ranging from 30 to 40 pounds of salt with 100 pounds of cottonseed meal, consumed nearly twice as much cottonseed meal as those hand-fed soybean pellets or cottonseed cake, and showed a somewhat greater gain as a consequence.

Jones (1930) reported a case of salt poisoning in a cow that received 1 pound of salt in buttermilk, repeated in 6 hours. An hour after the second dose the animal suffered severe spasms, marked weakness and diarrhea.

Pistor *et al.* (1950) found that adding 1 pound of salt to a maintenance ration for Hereford cows during a 190-day period did not affect reproduction or raise the sodium chloride content of the milk or blood, but did increase the chloride content of urine to a maximum of 2.36 percent. One pound of salt placed with 6 gallons of water through a fistula into the rumen of a cow caused an increase in salt concentration in the urine in 1 hour and in the blood in 2 hours, but in 24 hours the levels were back to normal. Two pounds of salt with 3 gallons of water caused the cow to show symptoms of salt toxicity and critical condition after 8 to 12 hours, but the cow recovered after the salt was flushed from the rumen. Two pounds given without water restriction caused no distress. These workers described symptoms of salt toxicity as anxiety and hypersensitivity to touch, followed by loss of coordination and finally collapse. Rumen contractions were increased in rate and intensity. They also presented evidence that sodium chloride is readily absorbed from the ruminant stomach, and that even under the stress of a 40 percent increase in blood-sodium chloride the kidneys can not eliminate urine at a higher concentration of sodium chloride than about 2.4 percent.

Savage and McIlvain (1951) found that salt can be used successfully to control consumption of cottonseed meal self-fed to Hereford steers on native range. The amount of salt needed to maintain meal consumption at a level of 2 pounds per head daily amounted to about 0.14 pound for every 100 pounds of liveweight. These workers found no particular difference in gain, bloom, blood constituents, or general well-being of steers self-fed salt mixtures as compared to others hand-fed the same amount of cottonseed meal. The salt-fed cattle consumed

slightly more than twice as much water as those not receiving the high salt intake, indicating the importance of adequate water supply when this method is used.

Procedure

Experiment 1—1949–50

Thirty-five Angus, Hereford and Shorthorn cows were divided into two groups as nearly alike as possible with respect to age, breed, weight and expected date of calving. They were started on wintering treatments December 8, 1949. Both groups had access to about 200 acres of unimproved upland pasture with an abundance of dry winter forage. Bluestem and Bermuda grasses constituted the major portion of the forage. The groups were alternated on the pastures every 2 weeks to minimize the effect of different pastures. One group was hand-fed 2 pounds of 41 percent protein cottonseed meal per head daily in feed bunks. The other group was given free access to a mixture ranging from 15 to 35 percent salt and 85 to 65 percent of 41 percent protein cottonseed meal.

Finely ground loose salt was used and all lumps were removed to insure a uniform mixture. Water was obtained from a stream about a quarter-mile from the feeding location.

Following this wintering trial, two dry cows were placed in dry lot where they were fed during the summer a mixed ration composed of 30 percent chopped alfalfa hay, 30 percent cottonseed hulls, 30 percent ground milo and 10 percent cottonseed meal with a mineral mixture free choice. Water was available at all times. Salt was introduced into the mixture in 1 percent increases by substituting it for cottonseed hulls in order to determine how high a salt intake cattle would take when self-fed a mixed ration and to observe the effect of this salt intake upon breeding cows.

Experiment 2—1950–51

The animals used in this experiment were commercial cows of mixed breeding. These cows were bred to calve in the fall and winter of 1950–51. The cows were divided into four groups of five as nearly alike with respect to stage of pregnancy, age and condition as possible. Three groups were self-fed, in dry lot, mixtures of cottonseed meal with salt enough to limit their intake of cottonseed meal to approximately 2 pounds per head per day. One of these three groups was fed hay at a level low enough to cause the cows to lose weight

rapidly. A second group was fed hay at a level calculated to maintain their weight, while a third group received all the hay they could consume. The fourth group served as a control and was self-fed hay and cottonseed meal in order to determine to what extent salt actually limited the intake of concentrates. The consumption of cottonseed meal by this group soon became excessive and thereafter was limited to 2 pounds per head per day by hand-feeding.

A rather poor quality Johnson grass hay was fed during the first 90 days in order to simulate the quality of forage which might be expected under range conditions in the winter. Following that, weathered hay composed of oats and alfalfa was used. Alfalfa made up an estimated 10 percent of the total. Weeds made up about another 10 percent. Because of the rather poor condition of the cows after 145 days of feeding, U. S. No. 1 extra leafy green prairie hay was fed for the remainder of the trial or 45 days. The cattle definitely improved in condition during this period.

At the beginning of the experiment, blood samples were drawn from all of the cows before salt feeding was begun, and analyzed for chlorides by the Whitehorn method as described by Hawk *et al.* (1947). Samples of blood and milk were drawn 2 days and 10 days after calving and at the termination of the experiment. Chlorides in milk were determined by first precipitating the protein and then using the Whitehorn method.

A metabolism trial was conducted to study the salt balance of cows on high salt intake as compared to that of cows receiving only a normal amount of salt. This also permitted a study of the pathways of salt excretion. Two cows from the sub-maintenance group (lot 1) which consumed the highest level of salt and two from the control group (lot 4) were placed in metabolism stalls. The total excretion of both feces and urine was collected for a period of 24 hours. Urine was measured by volume and feces by weight. Chloride content of the urine was determined by the Volhard-Arnold method as given by Hawk *et al.* (1947). The feces were extracted with water and the chlorides determined on the water extract by the same method as used for urine. Moisture content of feces was determined by drying in an electric oven for 24 hours at 105° C.

Four cows were selected for a digestion trial. Two were selected from lot 3, which was self-fed both the salt-cottonseed meal mixture and hay, and two from lot 4, which was hand-fed cottonseed meal but self-fed hay. The manual collection method was used for a 7-day

period. Feces were collected and weighed daily, and a 10 percent aliquot taken from each day's collection and stored under refrigeration. At the end of the 7-day collection period, all samples from each cow were thoroughly mixed and analyzed by standard A.O.A.C. methods (1949).

Results and Discussion

Experiment 1—1949–50

The feed and weight data are summarized in tables 1 and 2.

Both groups lost about the same amount of weight and weighed nearly the same at the close of the wintering period. The average

TABLE 1. CONSUMPTION OF SALT-COTTONSEED MEAL MIXTURES BY BEEF BREEDING COWS WINTERED ON PASTURE

Dates	Mixture		Feed Intake per Head per Day		
	Salt	Cottonseed Meal	Salt	Cottonseed Meal	Total
	%	%	lb.	lb.	lb.
Dec. 8–30	23	77	0.88	2.88	3.76
Dec. 31–Jan. 3	25	75	1.47	4.41	5.88
Jan. 4–7	31	69	1.32	2.93	4.25
Jan. 8–March 3 [1]	35	65	1.06	2.06	3.12
March 4–24	30	70	0.54	1.25	1.79
Average for 107 days [2]	..	..	0.95	2.19	3.14

[1] One cow died February 6.
[2] Weighted average.

intake of cottonseed meal was 0.19 pound higher per head daily for the self-fed group.

All of the cows did not calve before the close of the trial, but the calves from the salt-fed group weighed 2.05 pounds per day of age. Those from the hand-fed group weighed 1.93 pounds per day of age.

Periodic scouring was observed in five cows of the salt-fed group. One cow started scouring after 39 days, was too weak to weigh after 50 days and died after 60 days of feeding. She consumed no feed after 48 days. These difficulties were not observed in cows hand-fed 2 pounds of cottonseed meal per head daily.

From this experiment, it appeared that self-feeding mixtures of salt and cottonseed meal may cause scouring and death losses of

breeding cows when the daily salt intake is 1 to 1.5 pounds per head and the pasture and water conditions are similar to those existing in this trial. The cows did not appear to care for the winter forage and apparently did not consume enough to maintain their weight. Low nutritive content of the forage was doubtlessly largely responsible for the weight loss.

The observations on cows wintered on rather poor pasture suggested that the reaction to salt at a higher level of feed intake might be somewhat more favorable.

TABLE 2. WEIGHT, FEED AND CALF DATA FOR BEEF COWS WINTERED ON PASTURE WITH TWO METHODS OF SUPPLEMENTATION

Supplement Fed	Group 1 Salt-Cottonseed Meal Mixture	Group 2 Cottonseed Meal
Methods of feeding	Self-fed	Hand-fed
Number of cows	16 [1]	18
Number of days on feed	107	107
Initial weight, pounds	955	946
Final weight, pounds	799	791
Loss per head, pounds	156	155
Number of calves produced	13	12
Average age of calves at end of trial, days	79	85
Average weight of calves at end of trial, pounds	162	164
Average daily feed intake, pounds:		
Cottonseed meal	2.19	2.00
Salt	0.95	0.07

[1] There were originally 17 cows in this group but one died, presumably of salt poisoning although autopsy was not possible.

After the wintering study was over, two dry cows were placed in dry lot where they were fed during the summer a mixed ration as described in the procedure. Salt was gradually introduced in 1 percent increases by substituting it for cottonseed hulls in the mixture until the cows refused the mixture.

The cows consumed the feed mixture with relish, increasing their feed consumption rapidly until the mixture contained 9 percent salt. Increasing the salt from 9 to 10 percent caused a reduction of 2 pounds per head in feed intake but no other ill effects were noted.

Feed intakes remained about the same (23 pounds) until the mixture contained 14 percent salt, when it declined to 22 pounds daily. A further increase to 15 percent salt caused mass feed refusals and resulted in lowering the daily intake to 18 pounds for a time, then

to 12 pounds and finally the cows practically refused to eat the mixture at all. For 150 days these cows consumed over 2 pounds of salt per head daily with a peak intake of 3.30 pounds and an intake of over 3 pounds for a period of 40 days when the feed mixture contained 14 and 15 percent salt. During the first 121 days the cows made daily gains of 2.06 pounds per head and averaged 1.85 pounds for 152 days. They were very thin at the beginning, but became fat and sleek during the 243 days they were fed the ration containing salt.

Both cows calved at the end of the experiment, one while consuming the mixture containing salt and the other about a week after she had practically ceased eating the mixture. The first cow continued to eat the mixture in small quantity after calving. Her calf developed severe diarrhea and died when 5 days old, and she was taken off the mixture. Post-mortem examination and histopathologic studies of the calf showed no symptoms of salt toxicity, but some evidence of vitamin A deficiency. The latter is thought to be the cause of death since both blood and milk from the cow showed normal blood chloride levels. The second cow lost about 60 pounds during the week preceding calving because of her light feed consumption. Her calf appeared normal at birth, but the cow continued to refuse her feed causing a weight loss of about 200 pounds including loss at calving. She was finally taken off the salt mixture and fed silage with grain and cottonseed meal on which she slowly mended. Her calf was given vitamin A in capsules and grew somewhat slowly until it reached a saleable weight and was sold for veal. Both blood and milk from this cow also showed normal chloride levels. Carotene and vitamin A determinations were not made. Both of these cows lactated normally and rebred in a normal period after calving.

From this work it appeared that under conditions of ample feed and water supply, dry cows can tolerate an extremely high level of salt intake, but under conditions of short feed supply and a water supply not too readily accessible, cows may eat enough salt in a concentrate mixture to produce toxic effects, especially in winter when low atmospheric temperatures tend to lessen water intake. With good feed and water conditions in hot weather the reverse appeared to be true. These results suggested the experiment set up for 1950–51.

Experiment 2—1950–51

At the outset of this experiment, cows in lots 1, 2 and 3 were started on a mixture of 95 percent cottonseed meal and 5 percent salt. After they were consuming about 2 pounds of this mixture per

head per day, the salt content was increased whenever the cows consumed over 2 pounds of meal per day in an effort to stabilize consumption at the two-pound level.

The consumption of cottonseed meal was maintained quite close to the two-pound level throughout the course of the trial (figure 1). During the first two periods, the cows in lot 4 consumed considerably more cottonseed meal than those which were fed mixtures of cotton-

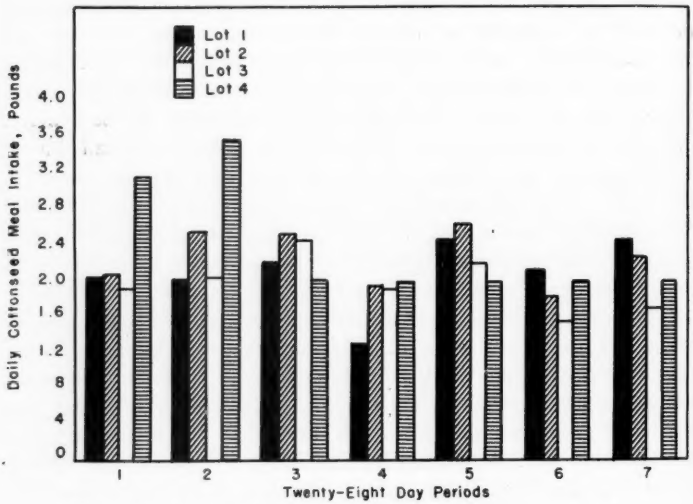

Figure 1. Average daily consumption of cottonseed meal.

seed meal and salt. This indicates very clearly that salt had a controlling effect on the consumption of cottonseed meal.

The consumption of salt (figure 2) increased gradually and in lot 1 the cows were consuming approximately 2 pounds of salt per day at the close of the trial. The cows in lots 2 and 3 which received more hay required a smaller amount of salt to maintain their consumption of cottonseed meal at the two-pound level. Salt consumption of cows in lot 4 which had free access to salt and bonemeal is in distinct contrast to the high intakes of cows in lots 1, 2 and 3.

Cows in lot 1 were limited to approximately 8 pounds of hay per head per day. Those in lot 2 were limited to approximately 11.5 pounds per day throughout the course of the trial (figure 3). Cows in

both lots 3 and 4 received all the hay they wanted but those in lot 3 consistently consumed a smaller amount of hay than those in lot 4.

There was a relatively minor difference between lots of cows in the consumption of water during the first four periods of the trial (figure 4). After that time, the difference in water consumption became more marked, probably, because the cattle were consuming a higher level of salt as well as existing under higher atmospheric temperatures.

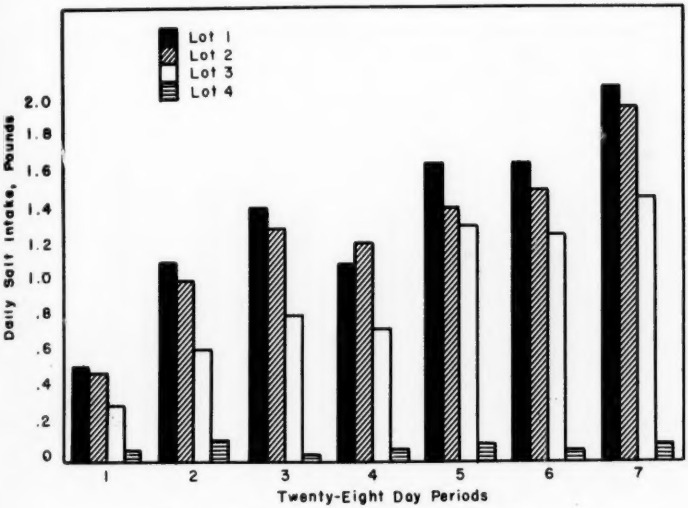

Figure 2. Average daily intake of salt.

The difference in water consumption was never as great as that indicated by Savage and McIlvain (1951). Cows in lot 4 which were not self-fed the salt mixture consistently consumed a smaller quantity of water throughout the trial than cows in the other three groups.

The nutritive content of the hay was not high enough to maintain any of the groups of cattle at constant weight (figure 5). Further, weight losses from each group can be partially attributed to weight loss at calving time. Weight losses for lots 1 and 2 are considerably greater than those for lots 3 and 4 which received a full feed of hay. The rather marked drop in weight during the first 112 days may be accounted for largely through calving losses. The weight curves after that time are more nearly representative of the actual perform-

ance of the cows brought about by variation in consumption of hay, cottonseed meal and salt.

The calves were weighed at birth and thereafter at the same time the cows were weighed. Calves from the cows receiving the higher levels of hay were considerably heavier than those from cows receiving low levels. This was to be expected because the cows in lot 1 especially were receiving less than a maintenance allowance of hay.

The average chloride content of the blood by groups at the begin-

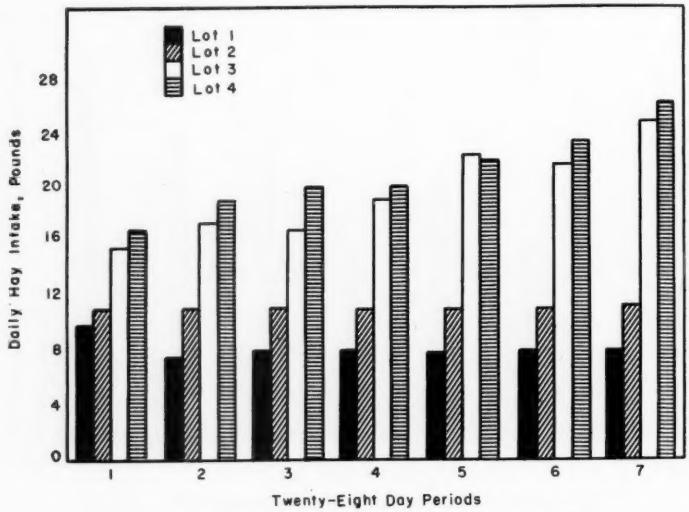

Figure 3. Average hay consumption per head daily.

ning of the experiment, 1 to 2 days after calving, 10 days after calving and at the termination of the experiment, are shown in table 3. There was no significant difference in blood chlorides between groups, and no difference between dates when all groups were considered, as shown by analysis of variance. There was, however, a significant difference between dates in the low hay group. The main difference of 38 mg. in favor of the final determination was highly significant.

The average chloride content of colostrum, normal milk (10 days after calving), and milk at the termination of the experiment is also shown in table 3. Due to the small number of observations, the data on milk chlorides were not analyzed statistically. There were no consistent differences between dates for milk chlorides and it may be con-

sidered that there are no real differences between periods or between lots.

A balance study on salt was conducted in an attempt to learn the pathway of excretion of the salt and also to learn more about the efficiency of absorption of salt from the digestive tract of the cow. During the period that the cows were on the balance trial, those receiving the high salt intake excreted approximately seven times the amount of urine excreted by the control cattle. At the time this trial was conducted, the average daily consumption of salt by the cows

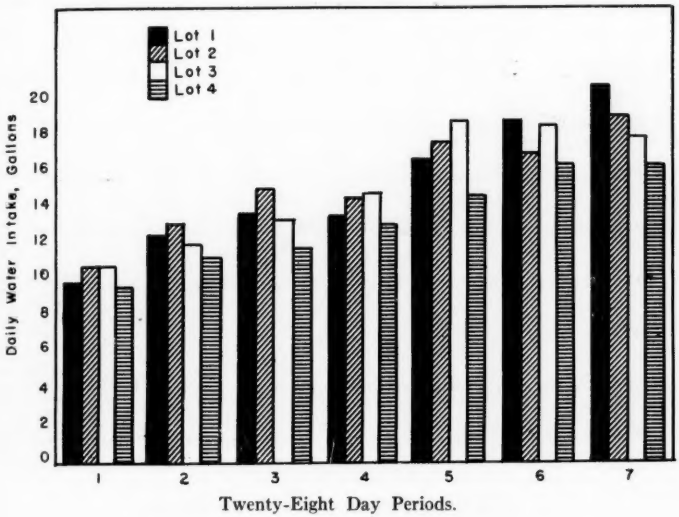

Figure 4. Average daily intake of water.

from the low hay group was 753.6 grams while the average daily consumption by the control group was only 48.6 grams. The average urinary excretion of salt from the cows fed the high salt diet for the 24 hour period was 941.7 grams. The average excretion of salt by the control cows was 58.6 grams. The average excretion of salt in the feces of the two cows receiving the salt mixture was 16.2 grams compared with an excretion of 24.7 grams by the control cows. Thus, absorption by the high salt cows was 97.8 percent as compared with 49.1 percent by the controls; this indicates great efficiency of absorption at the high salt level.

Total salt excretion (both urine and feces) from the high salt cows

was 957.9 grams or 2.1 pounds. Total salt excretion from the control cows was 83.3 grams or 0.2 pound. The negative salt balance may be explained by the fact that this trial was of short duration and the cows were somewhat nervous during the time they were confined. As a result, the excretion of urine was probably larger than would normally have been the case.

The efficiency of absorption from the digestive tract places a heavy load upon the kidneys since the tremendous amount of ingested salt

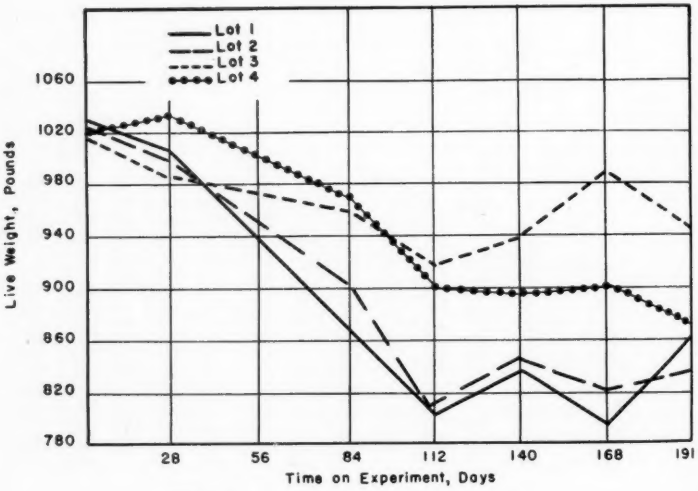

Figure 5. Average weights of cows.

must be voided through them. Furthermore, the kidneys are apparently very efficient in their handling of salt in as much as the data indicated no significant difference in level of blood or milk chlorides between the cows on high and normal salt intakes and 98.3 percent of the total excretion on the high salt level occurred through the kidneys. Pistor *et al.* (1950) found that salt not only is efficiently absorbed from the digestive tract, but actually may be absorbed in appreciable quantities from the ruminant stomach.

It is apparent from the data reported above and from the work of Pistor *et al.* (1950) that if cattle have a short adjustment period and have an adequate supply of water available at all times, they will be able to tolerate high levels of salt in their diet due to the

efficiency of kidney excretion. It was felt, at the beginning of this trial, that any deleterious effects that might result from the prolonged intake of high levels of salt might come as a result of kidney damage or through depression of digestibility of the feed. Histological study of the kidneys of two cows fed the high salt ration indicated that no harmful effects on the kidneys resulted from the high level of salt intake for a period of 190 days.

Rather surprisingly, data from the digestion trial showed a beneficial

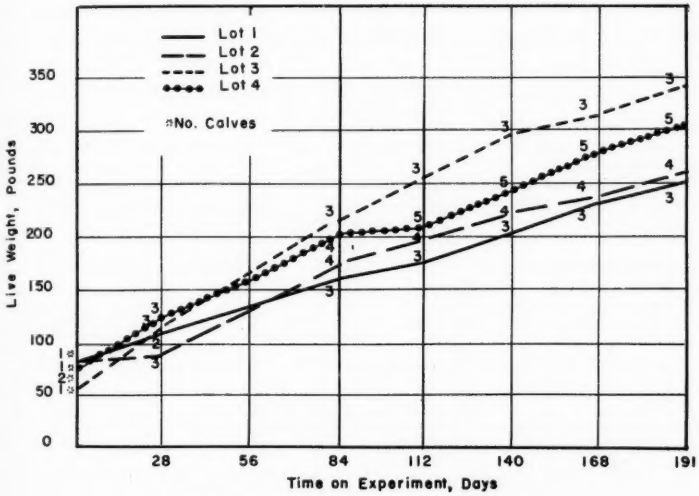

Figure 6. Average weights of calves.

effect of salt on digestion. The improvement in digestibility of protein by feeding high salt was in the magnitude of about 8 percent. The improvement in digestibility of crude fiber and nitrogen-free extract by feeding high salt was in the magnitude of about 5 percent. Ether extract digestibility indicated improvement, but variation was extremely large. Although the number of animals used was small, the data do show a definite trend confirming the report of Stanley (1949). Further investigation is needed on this point.

At the termination of the trial, two cows on the high salt intake were slaughtered and their digestive tracts checked for parasites. They were found to be completely negative.

The cows were bred as they came into heat after calving. Pregnancy

tests conducted at the termination of the trial indicated that conception occurred normally in all groups regardless of the level of salt consumed.

Feeding cottonseed meal and salt mixtures to breeding cows at different levels of nutrition proved very satisfactory in this feeding trial. No serious effects were noted in any of the groups of cows fed cottonseed meal and salt mixtures. Scouring occurred regularly, however, in all groups of cattle allowed free access to the salt mixtures. This scouring was never serious enough to present any great problem.

There was some difference in the appearance of the cows at the close of the experiment as to condition of hair and fleshing. In general, all cows maintained good appetites throughout the entire trial. Although

TABLE 3. AVERAGE CHLORIDE CONTENT OF BLOOD, COLOSTRUM AND NORMAL MILK

Level of salt intake, lb.	1.35	1.27	0.93	0.08
Level of hay intake	Low	Liberal	Full Fed	Full Fed
	mg. %	mg. %	mg. %	mg. %
Blood, beginning	599.3	612.5	601.4	605.3
Blood, 1–2 days after calving	635.6	622.6	628.4	583.0
Blood, 10 days after calving	623.9	616.6	597.8	606.7
Blood, end	637.2	611.9	602.0	601.2
Colostrum, 1–2 days after calving	234.5	292.6	303.0	220.7
Milk, 10 days after calving	201.0	293.7	222.4	222.6
Milk, end	230.3	226.5	258.1	247.6

all of the cows in lots 1 and 2 fed the low hay allowances were thin to the point of danger, they were no different than many undernourished range cattle during winter and drouth periods. All of the calves dropped by the cows in this trial were healthy and strong. No outward abnormal symptoms were observed among the calves from any group.

Summary

Results of two experiments in which mixtures of cottonseed meal and salt were self-fed to beef cows are presented.

Salt may be used to limit the consumption of concentrates from self-fed mixtures. No ill effects from the use of these mixtures were observed when cows were allowed to become gradually adjusted to the high salt intake and were given access to an abundant supply of water at all times.

No significant difference in blood chlorides was observed between

cows fed high levels of salt as compared to cows receiving only a normal salt intake. No differences in blood chlorides were observed between the beginning and end of the experiment when all groups were considered; however, there was a significant difference between blood chloride levels at the beginning and end of the experiment for cows self-fed a mixture of salt and cottonseed meal with a low intake of hay.

There appeared to be no real difference in chlorides found in the colostrum or normal milk either between treatments or between stages of lactation.

Cows fed a high salt allowance consumed considerably more water and excreted a much greater volume of urine than cows receiving only a normal salt allowance. Total chloride excretion of the high salt cows was 11.5 times that of the controls, 98.3 percent of which was excreted in the urine. Histological studies showed no kidney damage.

Data from a digestion trial indicate a beneficial effect of high salt intake upon digestibility of all the nutrients, particularly protein, crude fiber and nitrogen-free extract, with a less significant effect on ether extract digestion. Further investigation is needed.

High salt intake appeared to have no detrimental effect upon reproductive performance of the cows.

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THE EFFECT OF METHIONINE ON THE TISSUE DISTRIBUTION OF RADIOACTIVE COBALT INJECTED INTRAVENOUSLY INTO DAIRY CALVES [1]

RAY E. ELY,[2] K. M. DUNN,[3] C. F. HUFFMAN

Michigan Agricultural Experiment Station

and

C. L. COMAR [4] and GEORGE K. DAVIS

Florida Agricultural Experiment Station

PREVIOUS studies have demonstrated that cobalt produces certain toxic effects in the ruminant when administered intravenously (Dunn *et al.*, 1952; Ely *et al.*, 1946) and also when given in sufficient amounts orally (Ely *et al.*, 1946; Ely *et al.*, 1948; Keener *et al.*, 1947). During the course of studies on the physiological role of cobalt in ruminant nutrition, it was found that intravenously administered methionine was effective in reducing the toxicity of intravenously administered cobalt (Dunn *et al.*, 1952; Ely *et al.*, 1946). In view of the characteristic symptoms exhibited by the animals given toxic dosages of intravenously administered cobalt, studies were made of the tissue distribution of radioactive cobalt administered to five pairs of calves, one of each pair receiving cobalt alone and the other receiving methionine previous to the administration of cobalt.

Several reports (Burk *et al.*, 1946; Kondo and Hayashi, 1928; Michaelis, 1929; Michaelis and Yamaguchi, 1929; Schubert, 1931, 1933) have shown that cobalt forms coordination complexes with certain amino acids indicating that methionine might form a complex with cobalt which might render the latter less toxic or might have a distribution in the body different from administered inorganic cobalt. The nature and action of some of the physiologically important chelate complexes have been reviewed by Smith (1949) and Lehninger (1950). This paper reports the tissue distribution in paired calves of radioactive cobalt when injected intravenously at toxic levels with and without previous injection of methionine.

[1] Published with the approval of the Director of the Michigan Agricultural Experiment Station as Journal Article No. 1396.

[2] Present address: Bureau of Dairy Industry, U. S. Dept. of Agriculture, Washington, D. C.

[3] Deceased.

[4] Present address: UT-AEC Agricultural Res. Prog., Oak Ridge.

Experimental

Ten male dairy calves were paired into five groups and the pairs were sacrificed at five different time intervals, varying from 2 minutes to 12 hours after intravenous injection of cobalt. One calf of each pair was injected with cobalt sulfate containing radioactive cobalt and the second animal of each pair was given 500 mg. of methionine intravenously 2 to 3 minutes previous to the administration of the same amount of cobalt sulfate as the animal killed at the same time interval. All of the animals receiving the intravenous dosage of cobalt alone showed toxic symptoms of lacrimation, excessive salivation, rapid respiration, incoordination, defecation and urination. None of the animals receiving methionine intravenously prior to the cobalt administration showed these toxic symptoms. The same observations with additional animals have previously been made (Dunn *et al.*, 1952).

The radioactive cobalt was supplied by the Massachusetts Institute of Technology Radioactivity Center and was prepared by the bombardment of iron with deuterons. It was obtained as a purified solution of cobalt chloride and consisted of a mixture of three cobalt isotopes having a half life ranging from 65 to 270 days.

The animals were slaughtered and the tissue samples obtained by the procedure outlined by Comar, Davis and Taylor (1946). The samples were ashed, the ash brought into solution, and the activity measured with a dipping type Geiger-Muller counter tube using the procedure described by Comar and Davis (1947a).

The radioactive cobalt solutions containing sufficient additional inert cobalt for the production of toxic symptoms were prepared in Gainesville, and shipped to East Lansing for injection. The ashed tissue samples in solution were returned to Gainesville for the measurement of radioactivity.

Experimental Results and Discussion

The concentrations of labeled cobalt in the various tissues are presented in table 1. Two calves were killed at each time interval of 2 minutes, 5 minutes, 1 hour, 6 hours, and 12 hours following the injection of the cobalt. The effect of methionine injection prior to the injection of the cobalt solution may be noted by comparing the concentrations of cobalt in the various tissues of the paired calves sacrificed at the different time intervals following injection. Since the symptoms of toxicity of intravenously administered cobalt to calves are similar to those reported by LeGoff (1928) as a specific stimula-

TABLE 1. DISTRIBUTION OF LABELED COBALT IN TISSUES OF CALVES AFTER INJECTION OF TOXIC LEVELS WITH AND WITHOUT METHIONINE

Item	Experimental Conditions									
Calf No.	C649	C650	C629	C630	C627	C628	C626	C625	C622	C624
Wt. (lb.)	128	117	107	118	151	88	138	164	164	154
Inert cobalt (mg.)	50	50	75	75	75	75	75	75	75	75
Labeled cobalt (μg.)	450	450	60	60	60	60	60	60	60	60
Methionine (mg.)	0	500	0	500	0	500	0	500	0	500
Sacrificed after	2 min.		5 min.		1 hour		6 hours		12 hours	
Tissue	Micrograms Labeled Cobalt per 100 gm. Fresh Wt. Based on Dose of 100 Micrograms per 150 lb. Body Weight									
Pituitary	[1]	[1]	[1]	[1]	[1]	0.53	[1]	[1]	[1]	[1]
Thyroid	0.23	0.21	0.36	0.38	0.50	0.33	0.46	0.35	0.20	0.58
Thymus	0.12	0.10	0.11	0.14	0.12	0.07	0.15	0.09	0.10	0.07
Adrenals	0.33	0.32	0.44	0.45	0.34	0.32	[1]	0.31	0.26	0.29
Submaxillary gland	0.11	0.16	0.18	0.85	0.04	0.11	0.07	0.12	0.15	0.12
Parotid gland	0.16	0.20	0.31	0.30	0.07	0.10	0.08	0.16	0.10	0.11
Cerebellum	0.03	0.03	0.04	0.02	[1]	0.07	[1]	0.22	[1]	[1]
Cerebrum	0.02	0.01	0.03	[1]	[1]	0.01	[1]	0.03	[1]	[1]
Medulla	0.02	0.01	0.01	0.02	[1]	[1]	[1]	0.07	[1]	[1]
Spinal cord	0.02	0.02	0.04	0.06	[1]	[1]	[1]	0.06	[1]	[1]
Intestinal lymph nodes	0.17	0.25	0.21	0.22	0.20	0.12	0.10	0.22	0.05	0.10
Cecal lymph nodes	0.19	0.22	0.26	0.14	0.25	0.12	0.14	0.17	0.36	0.10
Colon lymph nodes	0.17	0.20	0.19	0.20	0.30	0.26	0.14	0.24	0.14	0.14
External lymph nodes	0.14	0.20	0.36	1.10	0.23	0.21	[2]	0.24	0.14	0.70
Heart	0.27	0.21	0.26	0.38	0.27	0.17	0.07	0.20	0.12	0.08
Blood	0.46	0.36	0.06	0.07	0.25	0.02	0.06	0.09	0.12	0.02
Lung	0.17	0.20	0.19	0.25	0.17	0.08	0.11	[2]	0.14	0.08
Kidney	0.63	0.61	1.10	1.50	0.67	0.46	0.46	0.53	0.31	0.43
Bladder	0.12	0.14	0.21	0.26	0.30	0.13	0.15	0.14	0.06	0.12
Urine (bladder)	0.08	0.13	0.30	1.70	1.30	11.00	1.20	3.50	3.50	1.70
Pancreas	0.46	0.53	0.03	0.77	0.70	0.49	0.49	0.64	0.62	0.27
Spleen	0.19	0.21	0.25	0.35	0.44	0.11	0.12	0.16	0.12	0.11
Liver	2.20	2.00	1.60	1.80	1.80	0.45	0.97	0.86	0.89	0.70
Bile	0.36	0.08	0.07	0.16	0.55	0.18	0.44	0.24	[2]	[2]
Leg muscle	0.10	0.08	0.08	0.05	[1]	0.04	[1]	[1]	[1]	[1]
Back muscle	0.05	0.05	0.05	0.07	0.04	0.03	[1]	[1]	0.02	[1]

[1] Radioactivity below detectable limits.

[2] Sample lost.

tion of the autonomic nervous system, comparisons were made of the concentrations of cobalt in certain nervous tissues of the paired calves. Various areas of the brain and spinal cord were analyzed to compare the concentration of labeled cobalt in these tissues from the calves that received methionine and those that did not receive methionine. There were very small differences in the concentrations of cobalt in the brain and spinal cord of each animal of the pairs sacrificed at 2 and 5 minutes after the injection of cobalt. This is the time interval that the most pronounced toxicity symptoms occurred in the animals not receiving methionine injections. If coordination complexes were formed with methionine and cobalt in the blood stream, their distribution to these tissues was apparently not affected. However, the combination of the cobalt and methionine may be less capable of producing excitation of the nervous tissue, thus preventing the toxicity symptoms observed in the calves receiving injections of cobalt only. Lehninger (1950) has pointed out that in certain groups of enzymes there are cases in which more than one metal may activate, and there are also some inhibitions by metals. Formation of a coordinated compound by cobalt and methionine might reduce the activation of an enzyme system by cobalt ions. That these compounds are not formed in the digestive tract is indicated by the report of Griffith *et al.* (1942) that methionine does not decrease the toxicity of orally administered cobalt in the rat as evidenced by a poor growth response. Orten and Bucciero (1948) also found that supplementation of a cobalt-containing diet did not inhibit the production of polycythemia. A decrease in the concentration of cobalt in the brain and spinal cord at the end of 12 hours coincides with the length of time for the alleviation of cobalt toxicity symptoms.

The highest tissue concentrations of cobalt were found in the liver, kidney, pancreas, blood, adrenals and heart of the animals sacrificed 2 minutes after the intravenous injections of cobalt. Lowest concentrations were found in the leg and back muscles, and the brain and spinal cord. These findings do not substantiate earlier statements (Mellor, 1935) that, "among the organs, the spinal cord and brain stand first in their power of picking up and storing the metal. The muscular tissue also retains a larger percentage than the liver or kidneys." The significance of different concentrations of labeled cobalt in the urine and bile at the various time intervals is difficult to evaluate because of varying amounts of material which may have

been present in the gall bladder and urinary bladder at the time of injection.

Figure 1 presents graphically the change in concentration with time for some of the tissues. With one exception the concentration was lower in the blood than that of the other tissues. Figure 1 demonstrates the rapid removal of cobalt from the blood particularly by the liver, pancreas and spleen. The spleen and kidney showed a peak

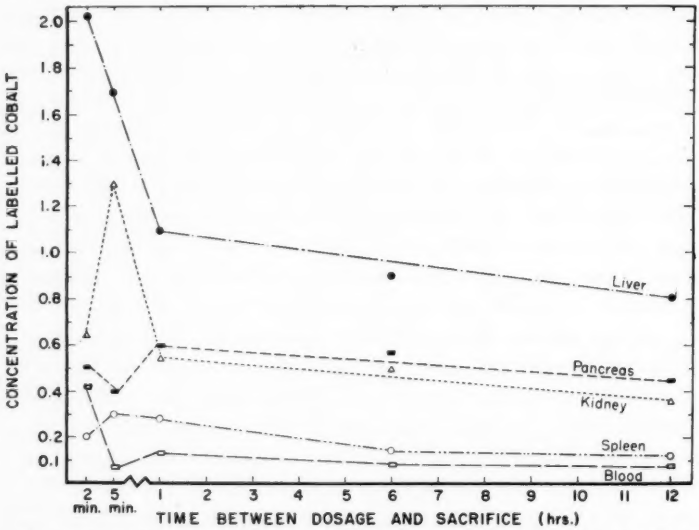

Figure 1. Distribution of labeled cobalt in selected tissues of the calf at varying times after intravenous injection (concentration expressed as micrograms of labeled cobalt per 100 grams fresh weight based on dose of 100 micrograms per 150 pounds body weight).

concentration at 5 minutes after injection whereas this occurred at 1 hour in the pancreas. Relatively high concentrations of cobalt in the lymph nodes, kidney, liver, bile and urine indicated the principal excretory pathways of intravenously injected cobalt by the bovine.

Failure to detect cobalt in the pituitary gland was due principally to the small sample available. The other endocrine glands examined had relatively high concentrations of cobalt up to 12 hours after injection. The concentrations of labeled cobalt in all of the organs examined are in agreement with those previously reported for the bovine (Comar, Davis and Taylor, 1946; Comar *et al.*, 1946; Comar and Davis,

TABLE 2. RECOVERY OF LABELED COBALT IN TISSUES OF CALVES AT VARIOUS INTERVALS FOLLOWING INJECTION WITH AND WITHOUT METHIONINE

Item	Experimental Conditions									
Calf No.	C649	C650	C629	C630	C627	C628	C626	C625	C622	C624
Inert cobalt (mg.)	50	50	75	75	75	75	75	75	75	75
Labeled cobalt (μg.)	450	450	60	60	60	60	60	60	60	60
Methionine (mg.)	0	500	0	500	0	500	0	500	0	500
Sacrificed after	2 min.		5 min.		1 hour		6 hours		12 hours	
Tissue	Percentage of Dose in Whole Tissue									
Thyroid	0.05	0.02	0.13	0.07	0.11	0.05	0.27	0.12	0.04	0.21
Thymus	[1]	[1]	0.22	0.18	0.24	0.12	0.13	0.12	0.15	0.12
Adrenals	0.01	0.02	0.03	0.02	0.02	0.02	0	0.02	0.03	0.01
Cerebellum	0.01	0.01	0.31	0.01	0	0.03	0	0.06	0	0
Cerebrum	0.04	0.02	0.07	0	0	0.03	0	0.05	0	0
Medulla	0.01	0.01	0.01	0.01	0	0	0	0.03	0	0
Heart	1.40	0.88	1.10	1.70	1.00	0.92	0.30	0.68	0.47	0.33
Blood	24.00	18.00	3.40	3.80	13.00	8.60	3.30	4.50	6.00	0.81
Lung	1.20	1.50	2.00	1.60	1.30	0.94	1.10	[1]	1.00	0.50
Kidney	1.90	1.70	3.70	3.90	2.00	1.90	1.50	1.30	1.20	1.20
Pancreas	0.28	[1]	0.03	0.30	0.43	0.41	0.30	0.41	0.35	0.25
Spleen	0.28	0.33	0.46	0.27	0.75	0.28	0.22	0.28	0.22	0.15
Liver	21.00	20.00	19.00	18.00	21.00	8.60	13.00	11.00	13.00	7.80

[1] Recovery not determined.

1947a, b) where comparable intervals following injections are available.

The percent of the dose of labeled cobalt that was present in the various tissues at different intervals following injection is given in table 2. Two minutes after injection the blood would have completely circulated through the vascular system more than two times, assuming the circulation time to be somewhat less than 60 seconds. One must also consider that this length of time may not permit thorough mixing of the injected cobalt. It is interesting to observe, however, that approximately 20 percent of the injected dosage remained in the blood stream after 2 minutes and that approximately 20 percent was in the liver. The percentage of the total dose given that was found in the liver remained relatively high at each of the intervals studied throughout the 12 hour period following injection.

Summary

While intravenously administered methionine prevented the physiological symptoms observed when high doses of cobalt were administered intravenously, it did not alter the distribution of cobalt in the tissues investigated.

Toxic doses of cobalt administered intravenously are rapidly removed from the blood. The concentrations in the liver, kidney and lymph system remains relatively high for at least 12 hours following the intravenous administration of cobalt. The principle excretory pathways are apparently the kidney, liver and lymph system.

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BLOOD VOLUME OF FARM ANIMALS[1]

SAM L. HANSARD, WILLIAM O. BUTLER,[2] C. L. COMAR and C. S. HOBBS

UT-AEC Agricultural Research Program and Tennessee Agricultural Experiment Station[3]

A CONVENIENT and reliable method of estimating the blood volume of farm animals might well be of importance from the following points of view: (a) there would be provided a measure of the animal's size and physiological state, which after adequate correlation might be employed as we now use body weight and hemoglobin; (b) it would be possible to evaluate changes in the body fluid volumes caused by nutritional, physiological or pathological disturbances such as pregnancy, lactation, obesity, shock, renal diseases, thyroid disorders and others; (c) it would enable calculation of the total amount of any substance in the blood from the blood concentration value; and (d) by the use of labeled blood components it would be possible to determine the acutal blood content of organs and tissues under varying experimental conditions.

There is little information in the literature on procedures and values for the blood volume of domestic animals (Turner and Herman, 1931; Miller, 1932; Gotsev, 1939; Courtice, 1943; Duke, 1947; Hansard *et al.*, 1951). However, in clinical investigation the importance of this type of study has given rise to a voluminous literature dealing with methods and results on laboratory animals and man. Comprehensive reviews on the subject have been compiled by Reeve (1948) and Gregersen (1951). The principle methods for estimation of blood volume in the intact animal are based upon measurement of the dilution in the bloodstream of a known amount of some test substance. These test substances are usually erythrocytes which have been labeled with P^{32}, Fe^{59}, K^{42}, or Cr^{51}, or substances which follow the plasma proteins such as T 1824 dye or I^{131} labeled proteins. Intercomparison of methods has led to recognition of many theoretical

[1] This article is published with the approval of the Director of the University of Tennessee Agricultural Experimental Station. The radiosotopes used in this study were obtained from the U. S. Atomic Energy Commission. The authors wish to express their appreciation to Dr. B. F. Trum and Dr. H. E. Sauberlich for their assistance with the burro studies.

[2] A portion of this study was conducted for partial fulfillment of the requirements for the M.S. degree from the University of Tennessee.

[3] Animal husbandry department.

problems. These involve such considerations as amount of trapped plasma in the packed red cells, relationship of average body hematocrit to venous hematocrit, and leakage of the tagged substances from the bloodstream. The emphasis in the present work has been upon establishment of acceptable values of total blood volume by a single method which is suitable for routine use, and known to give reasonably reliable estimates, although admittedly arbitrary in some respects.

In this study the P^{32} labeled red cell method was employed since the procedures were relatively simple and the total blood volume could be calculated without use of the hematocrit value. This paper describes the procedures as used with sheep, swine, cattle and burros and presents total blood volume values for these animals at various ages and weights.

Experimental

The sheep, swine, cattle, and burros used in these studies were normal, healthy individual animals maintained under typical summer farm management conditions.

The procedures used were based on those discussed in considerable detail by Reeve and Veall (1949) and have been outlined by Hansard *et al.* (1951) for swine. In general, the method is as follows: (a) a blood sample is drawn from the animal, (b) whole blood is incubated with P^{32}, (c) red blood cells are washed to remove any P^{32} not in the cells, (d) the cells are reconstituted to the original volume, (e) a known volume of suspended cells is injected into the immobilized animal and (f) after mixing has occurred a blood sample is taken from the animal and the radioactivity measured for calculation of the dilution that has occurred.

On the basis of studies to be described later, the following detailed procedures have been found most convenient under our conditions. Methods for handling the animals (Hansard, 1951) and performing the injections have been previously described (Hansard *et al.*, 1951). Damage to the red blood cells was minimized by gentle handling and the use of heparinized containers and syringes.

From the restrained animal, 5 to 15 ml. of blood was taken, heparinized and placed in a 50 ml. Erlenmeyer flask. Five to 10 microcuries of P^{32} in a minimum volume of neutralized isotonic saline were added per milliliter of blood and the mixture incubated in a shaker unit at 37.5° C. for 4 hours. The blood was then centrifuged and the red blood cells washed four times with ice-cold physiological

saline which removed all but insignificant amounts of the radioactive plasma. The labeled red cells for each animal were then reconstituted to the original volume of blood with saline and within a few minutes a measured volume of from 2 to 10 ml. of the homologous erythrocytes were quantitatively injected into the jugular or ear vein of the immobilized animal. Venous samples were drawn at 10 to 15 minutes after injection for hematocrits and measurement of activity. The latter was accomplished simply by placing a standard volume of whole blood or an aliquot of lysed red cells, usually 10 ml., in a 60 mm. diameter Petri dish below an ordinary end-window Geiger counter. It is necessary, when whole blood is used, that the sample be processed and the count completed before any appreciable settling of the red cells. The standard was prepared by dilution of 1 ml. of the cell preparation (used to inject the animal) to 250 ml., from which 10 ml. were taken and measured in the same way as described for samples above.

The amounts of blood and activities as listed gave samples in the normal counting range. For smaller animals, the lower values of blood and activity were used whereas for larger animals the larger quantity was used. The dilution factors were, of course, arbitrary but were convenient under our conditions. Blood volume calculations were then made as follows:

A=counts per minute of 10 ml. of the solution made by dilution of the injection preparation 1 to 250

B=milliliters of injection preparation administered to the animal

C=counts per minute of 10 milliliters of whole blood taken post-injection of the labeled cells

W=body weight in kilograms

D=volume of blood of animal in milliliters

BV=blood volume in milliliters of blood per 100 grams body weight

F=correction factor as calculated from the percent loss *in vivo* before the 15 minute blood sample is taken and/or *in vitro* losses when these are known to be significant [4]

(a) $D=\frac{(250)(A)(B)}{C}\times F$=milliliters of blood in the animal

(b) $BV=\frac{(25)(A)(B)}{(C)(W)}\times F$=milliliters of blood per 100 grams body weight

[4] When the labeled red cells are injected within a few minutes after the final washing *in vitro*, loss of activity to the saline wash is insignificant. In this study blood samples were taken at 15 minutes after dosing and appropriate corrections made. If, however, these samples were taken at 5 minutes after administration of the labeled cells, mixing would be complete, and the *in vivo* loss and corresponding error would be well within the limits of the experimental errors. Thus, calculated correction would be unnecessary. These matters are discussed further in the presentation of the results.

Results

In vitro *Uptake,* in vitro *Loss and* in vivo *Loss of* P^{32} *from Red Blood Cells*

It is necessary to know the magnitude and rate of P^{32} uptake by the cells to permit estimation of the amounts of radioactivity to be used, and to allow choice of a suitable incubation time period. Table 1 shows the percent uptake at various times for the cells of the mature and young of the species studied. These values were obtained as described under experimental procedure, except that larger initial amounts of blood were incubated and aliquots were taken at the stated time intervals. The amount of P^{32} found in the red blood cells of the aliquot, multiplied by the aliquot factor to give the P^{32} content of the sample at that time, was calculated as a percentage of P^{32} originally added to the incubated sample. As may be noted from table 1, the percent uptake at the end of 4 hours incubation ranged from about 13 for sheep and cattle to 26 for swine and burros. There appeared to be little difference in the rate of uptake or in the comparative uptake of P^{32} by cells from the young and the old. An incubation time of 3 hours was considered to be most practical due to the decreased rate of uptake after this time. It is essential that the labeled cell suspension be injected into the animal before occurrence of any significant loss of P^{32} from the cells to the physiological saline. Experiments indicated that this loss from the cells into the saline was about 5 percent during the first hour. To minimize this error the final cell suspension was administered to the immobilized animal within minutes after its preparation; any extended delay would require that an aliquot of the cell suspension be immediately centrifuged and the saline counted to provide the correction factor for the free P^{32} at the time of dosing.

Following administration of the labeled cells to the animal, it is necessary that the blood sample be drawn sometime after complete mixing in the animal's blood has occurred, and before there has been any significant loss of P^{32} from the red cells or loss of red cells from the circulation. It is considered that mixing is probably complete within 3 minutes after injection. The *in vivo* loss of P^{32} from the blood of the various species was determined experimentally and typical results are reported in table 2. These values were calculated by plotting the activity of the blood samples of the individual animals at two or more time intervals and extrapolating back to zero time; from this zero time figure the actual percent *in vivo* loss at the times indicated

was calculated. These curves were employed for the correction in the calculation of the reported blood volume values.

Blood Volume of Sheep

Twenty blood volume determinations were made with 16 Hampshire sheep of different ages and weights as indicated in table 3. The lambs were unshorn and the mature sheep carried a 5 months' fleece. Cell pack volumes are presented to allow estimation of the plasma volume; these were determined in all cases by centrifugation for 30 minutes at 1800 r.p.m., 25 cm. radius, and were corrected for 5 percent trapped plasma (Leeson *et al.*, 1951).

TABLE 1. ACCUMULATIVE PERCENT UPTAKE OF P^{32} *IN VITRO* BY THE RED CELLS OF THE VARIOUS SPECIES OF FARM ANIMALS

	Hours Incubated at 37.5° Centigrade				
Animal	0.5	1	2	3	4
Mature sheep	3	5	8	10	13
Lamb	2	4	7	9	11
Mature swine	7	12	17	25	26
Pig	11	16	21	24	25
Mature bovine	3	6	10	12	14
Calf	2	4	6	11	15
Mature burro	6	10	16	20	23
Colt	6	9	12	19	24

The blood volume of 6.3 ml. per 100 grams body weight for the 6-month-old lambs was significantly lower than that of 8.0 for the 1-month lambs; the values for the 1-year-old and 3-year-old sheep of 5.5 and 5.8, respectively, were slightly lower than that of the 6-month animals. The high values for the 7-year-old ewes may have been due to the fact that these animals were extremely thin. Berlin *et al.* (1951) has pointed out that the absence of fat will tend to increase the blood volume value. The values here reported agree with those of Dukes (1947) insofar as they indicate a rapid decrease of blood volume with increasing age during early life, with a gradual leveling off after the animals are a few months old. It should be noted, however, that the absolute values here given for mature sheep are lower than those reported by Dukes (table 8).

TABLE 2. ACCUMULATIVE PERCENT LOSS OF P^{32} *IN VIVO* FROM THE RED CELLS OF FARM ANIMALS

Species	15 Min.	30 Min.	1 Hour
Sheep	12	25	48
Swine	6	14	20
Bovine	10	20	40
Burro	10	23	50

Blood Volume of Swine

A detailed procedure and results of blood volume determinations with swine have been previously reported (Hansard *et al.*, 1951), but are summarized in table 4 for ease of comparison. It may be noted that the blood volume ranged in regular fashion from 7.4 to 3.5 for 10 lb. and 675 lb. animals, respectively. In comparison with other species, there are two interesting points, both of which are probably related to the percentage fat in the swine carcass: (a) the absolute values for blood volume were lower than those of other animals, especially at the heavier body weights, and (b) the blood volume value tended to decrease with increasing body weight to a greater extent than with other species. This was especially noticeable at the usual ages when growth is retarded and fat laydown is increased.

Blood Volume of Cattle

Determinations with 18 Hereford cattle gave blood volume values ranging from 12 ml. per 100 grams body weight for day-old calves to 5.7 for 8- to 12-year-old cattle. The trends were the same as those for swine and sheep with the values being high for the very young,

TABLE 3. BLOOD VOLUME OF SHEEP AT VARIOUS AGES AND WEIGHTS

Number of Animals	Age	Weight	Cell Pack Volume		Ml. Blood per 100 gm. Body Weight	
		pounds	mean	std. error	mean	std. error
5	1 month	27	45	1.1	8.0	0.2
4	6 months	92	47	1.9	6.3	0.1
4	1 year	135	47	3.0	5.5	0.3
4	3 years	156	34	0.5	5.8	0.3
3	7 years [1]	115	37	2.9	8.0	0.4

[1] These aged ewes were extremely thin and two were in late lactation.

TABLE 4. BLOOD VOLUME OF SWINE AT VARIOUS AGES AND WEIGHTS

Number of Animals	Age	Weight	Cell Pack Volume		Ml. Blood per 100 gm. Body Weight	
		pounds	mean	std. error	mean	std. error
3	2 weeks	10	36	2.0	7.4	0.3
4	4 weeks	20	41	0.5	6.7	0.1
8	3–4 months	98	38	2.0	6.3	0.1
3	4–5 months	122	37	0.4	5.9	0.3
3	7–8 months	182	40	0.2	5.4	0.5
4	2 years	344	38	0.6	4.6	0.2
3	3 years	675	48	1.2	3.5	0.3

but apparently unaffected by weight or age in animals older than 2 to 3 months. Turner and Herman (1931) reported lactating cows to have a 25 percent higher blood volume than non-lactating animals. The four oldest animals in table 5 were in late lactation, but there was no apparent effect on the blood volume.

Blood Volume of Burros

A summary of 50 blood volume determinations made with 37 burros is given in table 6; about half of these were measured by the I^{131} procedure (Storaasli, 1950). The possibility of using iodine^{131} labeled plasma was studied because for routine work this would avoid the labeling of red cells from individual animals and would therefore be much more convenient. Defibrinated burro blood plasma was iodinated by the Abbott Laboratories. Each animal was injected with about 200 microcuries of the preparation and the blood sample taken 15 and 30 minutes later. The hematocrit was determined in the usual way

TABLE 5. BLOOD VOLUME OF CATTLE AT VARIOUS AGES AND WEIGHTS

Number of Animals	Age	Weight	Cell Pack Volume		Ml. Blood per 100 gm. Body Weight	
		pounds	mean	std. error	mean	std. error
2	2–6 days	60	39	3	12.0	...
1	3 weeks	108	30	..	8.5	...
3	2–3 months	243	45	3	6.2	0.3
5	6–8 months	544	39	3	5.8	0.3
3	14–15 months	747	38	2	5.7	0.5
4	8–12 years	1045	41	1	5.7	0.4

and 0.5 ml. of plasma was evaporated to dryness for counting in a 4.75 cm.^{2} stainless steel cup. The standard was prepared from a known aliquot of the solution injected, and counted in the same manner as the plasma sample. It was determined that no self-absorption corrections were necessary under the conditions used. The total blood volume was then calculated from the plasma volume and the hematocrit corrected for 5 percent trapped plasma.

There was very close agreement between the values obtained by the P^{32} labeled cells and the I^{131} labeled plasma methods. It may first be noted that the 19 percent value for the 1-day-old colts was high and

TABLE 6. BLOOD VOLUME OF BURROS AT VARIOUS AGES AND WEIGHTS: EFFECT OF LACTATION: COMPARISON OF P^{32} AND I^{131} METHODS

Method	Number of Animals	Age	Weight	Cell Pack Volume		Ml. Blood per 100 gm. Body Weight	
			pounds	mean	std. error	mean	std. error
I^{131}	2	1 day	49.5	52	3	19	0.9
P^{32}	4	1–3 months	110	38	0.8	9.5	0.2
I^{131}	6	1–2 years	300	34	2	7.1	0.6
P^{32}	2	2 years	274	35	...	6.7	...
I^{131}	7	3 years	353	36	2	6.4	0.4
P^{32}	2	3 years	373	36	...	6.5	...
I^{131}	9	4 years	346	37	1	6.6	0.4
P^{32}	13	4 years	330	35	0.4	6.2	0.1
P^{32}	5 (lactating)	4 years	395	37	2	7.9	0.2

is in agreement with that reported by Gotsev (1939) for newborn lambs. The 1- to 3-month-old colts showed higher values than did the mature burros; among the mature animals there was no appreciable difference between 1- and 4-year-olds. As indicated in table 6, the blood volume value for five burros in early lactation was about 25 percent higher than the average values for the other mature burros; since there was no great difference in condition, this may be interpreted as being due to the state of early lactation (Turner and Herman, 1931).

Repeated Blood Volume Determinations on the Same Animal

In order to estimate the variation in blood volume from week to week and to demonstrate the feasibility of making weekly determinations, 12 blood volume measurements were made on three mature

burros over a four-week period using the P^{32} procedure and the results are summarized in table 7. Values were corrected for any residual activity in the blood from the previous determination. It is evident that any variation from week to week was of the same order of magnitude as the variation between animals and probably less than the experimental errors. This would indicate this procedure to be practical for repeated determinations on the same animal so long as there is a significant difference between the injected radioactivity and the residual radioactivity in the blood at the time of sampling.

Discussion

The P^{32} labeled red cell method for determination of blood volume has been found convenient and capable of yielding reproducible results with the species studied. The method would be even simpler if it

TABLE 7. REPRODUCIBILITY OF FOUR WEEKLY BLOOD VOLUME DETERMINATIONS ON THE SAME BURROS (4-YEAR-OLD MALES)

Animal Number	Number of Determinations	Weight	Cell Pack Volume		Ml. Blood per 100 gm. Body Weight	
		pounds	mean	std. error	mean	std. error
41	4	288	35	0.8	6.2	0.2
148	4	345	35	1.0	6.1	0.2
43	4	358	34	0.7	6.2	0.2

were possible to use red cells from a single donor animal for all the animals of that species to be measured at one time. This has been the usual practice with rats (Berlin *et al.*, 1949, 1951; Sharpe *et al.*, 1950). However, Nickerson *et al.* (1950) have pointed out that, in dogs, blood incompatabilities have caused discrepancies in the measurement. In a few studies in this laboratory, labeled red cells from one individual have been used in others of the same species with no apparent interference in the measurement. Nevertheless, the possibility of blood incompatibility should be taken into account if this time-saving modification is used. This avoidance of drawing blood from each animal for incubation is also accomplished by the use of the I^{131} labeled plasma. Although excellent results were obtained with the burro, it was not found possible to get reasonable and consistent values by this method with sheep, swine or cattle. Accordingly, the I^{131} method

is not recommended for general usage with domestic animals until this species difference is further studied.

It should be noted that for the dilution methods in general, the experimental errors almost invariably lead to high values for the blood volume. Some of the more important sources of error include:

TABLE 8. COMPARATIVE BLOOD VOLUME OF FARM ANIMALS

Species	Number of Animals	Age	Average Weight	Method	Ml. Blood per 100 gm. Body Weight		Reference
			pounds		mean	std. error	
Sheep	4	1 day	7	Congo Red Dye	16.9	...	Gotsev (1939)
	4	3–4 days	16	Congo Red Dye	10.9	...	Gotsev (1939)
	5	4 weeks	27	P-32	8.0	0.2	This paper
	4	3 years	156	P-32	5.8	0.3	This paper
	..	.....	..	.....	8.0	...	Dukes (1947)
Swine	3	2 weeks	10	P-32	7.4	0.3	Hansard *et al.* (1951)
	4	4 weeks	20	P-32	6.7	0.1	Hansard *et al.* (1951)
	8	3–4 months	98	P-32	6.3	0.1	Hansard *et al.* (1951)
	4	2 years	344	P-32	4.6	0.2	Hansard *et al.* (1951)
	3	3 years	675	P-32	3.5	0.3	This paper
Bovine	2	2–6 days	60	P-32	12.0	...	This paper
	1	3 weeks	108	P-32	8.5	...	This paper
	5	6–8 months	544	P-32	5.8	0.3	This paper
	..	growing	..	Dye	5.81	...	Turner and Herman (1931)
	..	cow	..	Dye	6.38	...	Turner and Herman (1931)
	..	cow	..	Dye	6.70	...	Miller (1932)
	4	8–12 years	1045	P-32	5.7	0.4	This paper
	..	Bullock	..	.....	7.7	...	Dukes (1947)
Equine							
Burro	2	1 day	49	I^{131}	19.0	0.9	This paper
	4	1–3 months	110	P-32	9.5	0.2	This paper
	9	4 years	346	I^{131}	6.6	0.4	This paper
	13	4 years	330	P-32	6.2	0.1	This paper
Horse	2	.....	..	.....	7.2	...	Courtice (1943)
	..	.....	..	.....	9.7	...	Dukes (1947)

(a) non-quantitative injection into the bloodstream, (b) loss of label from cells before injection, and (c)removal of label from circulating blood following administration to the animal. In this study every precaution was taken to eliminate or correct for these errors and by management practices to avoid physiological changes that are known to affect the normal individual.

For comparative purposes the blood volume values for the various species of farm animals of different ages and weights, as reported in this paper and in the literature, have been compiled in table 8. Methods used and references are cited for convenience of comparison. It will be

noted that relatively few values were found in the literature, and there was no systematic attempt to show the relationships between weight and blood volume. In general, the values reported in this study were lower than those found in the literature. Our data show swine to have the lowest blood volume, especially at the heavier weights, and the burro to have the highest blood volume value, with little difference between that for cattle and sheep at corresponding ages. The higher fat content found in swine could account for this lower blood volume (Berlin *et al.*, 1951). The high blood volume of the very young animals is in agreement with the findings of other investigators as reported by Dukes (1947).

The data in this paper may also be considered from the standpoint of the total amount of blood in the animal body. It is obvious that, except for swine and the very young, there was a quantitative linear relationship between the amount of blood and body weight. Therefore the relationship between total blood and age would follow the same pattern as between body weight and age, which has been well documented in the literature (Brody, 1945).

The reliability of the blood volume estimation as a measure of animal size, and the possibility of its use to indicate the degree of fatness, must await further study. There is also need for the evaluation of the changes in body fluid volumes which may be caused by a variety of physiological factors of interest to the nutritionist.

Summary

A simple procedure is described for measurement of blood volume of farm animals based on the phosphorus labeled red cell method. The blood volume values are reported for 20 sheep, 28 swine, 18 cattle and 50 burros of variable ages and weights, and a summary of these findings, together with those in the literature, is presented for comparative purposes and to provide basic values for the normal animal.

Consideration of these data indicated that:

1. The newborn of all species studied demonstrated a high blood volume.
2. In the case of swine, the blood volume decreased significantly with increasing weight and the comparative absolute values were lower than for other species. This is considered as due to the high percent of body fat.
3. Blood volume values for cattle, sheep and burros over 2–3 months of age showed no effect of age or weight. The values

for the burro were highest, while there was little difference between those of cattle and sheep which fell between those for swine and the burro.

It is suggested that the widespread use of the simple procedure here described may lead to correlations which could provide additional measurements ot body size, nutritional levels, and physiological status of farm animals.

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NEWS AND NOTES

The forty-fifth annual meeting of the American Society of Animal Production will be held in the Hotel Sherman in Chicago, Illinois, on November 27 and 28, 1953, with a dinner for the honored guest on November 29. Members planning to present papers are reminded that titles must be in the hands of the secretary, Dr. J. I. Miller, Department of Animal Husbandry, Cornell University, Ithaca, N. Y., by July 20, following which abstracts must be filed with him by August 15.

Nominations for the Morrison Award, in writing, are due in the Secretary's Office by June 15. All members of the Society except members of the Executive Committee and the Award Committee are eligible to make one nomination. The rules governing this award were amended in 1952 and are as stated in the JOURNAL OF ANIMAL SCIENCE, Vol. 11, No. 4, pp. 807–809. All nominations must be accompained by a brief biography of the nominee and a list, together with copies, of publications concerning the research, and a statement of the importance to the livestock industry of the work upon which the nomination is based. The cash award for 1953 has been increased to $1,250.

Nominations for American Feed Manufacturers Award should be sent to the Secretary's Office by June 15. The rules governing this award are unchanged and are as stated in the JOURNAL OF ANIMAL SCIENCE, Vol. 7, pp. 257–258, 1948. No formal nominations from the membership are required, although the Award Committee would appreciate receiving nominations. Research published in 1951 and 1952 will be considered for the 1953 Award.

P. S. Shearer, Head of the Animal Husbandry Department at Iowa State College, has been chosen as the honor guest for the American Society of Animal Production at its meeting November 27 and 28. His portrait will be presented to the Saddle and Sirloin Club at the time of the banquet in his honor on November 29. J. L. Lush is chairman of the committee in charge of arrangements for the event.

The committee on Ralston-Purina Fellowship Awards has selected the winners for the school year 1953–54. The principals named for Animal Husbandry are James M. Fransen of Oklahoma A & M and Joseph P. Fontenot of Southwestern Louisiana. The institutions at which these men preferred to work were Purdue and Oklahoma A & M, respectively. The Dairy Husbandry principals were Walter E. C. Moore of New Hampshire and Harold A. Ramsey of Kansas State. These men preferred Wisconsin and North Carolina, respectively. The principals for Poultry Husbandry were Ernest Williams of Southwestern Louisiana and Hans Fisher of Rutgers. Louisiana State and Illinois were the institutions at which these men preferred to continue their work. Merthyr L. Miner of Utah and Iowa was named as Veterinary Science principal. He preferred Minnesota for graduate training. Alternates were Elwyn R. Miller and Norman R. Piersma of Michigan State, LeRoy F. Nelson of Nebraska, Rodney L. Preston of Colorado A & M, Dero S. Ramsey of Mississippi State, Billy E. Welch of Abilene Christian and Charles L. Woronick of Connecticut. These awards in the amount of $1,560 each annually are made on a yearly basis. The nature of and some of the rules governing these awards were published in the JOURNAL OF ANIMAL SCIENCE, 1951, Volume 10, page 307.

Marshall C. Hervey, associate professor of dairy husbandry and in charge of dairy cattle breeding work for the University of Minnesota, passed away January 25 at the University of Minnesota Hospitals.

D. W. Colvard, Head of the Animal Industry Department at North Carolina State College and Agricultural Experiment Station since 1948, has been named

Dean of Agriculture at that Institution. He succeeds Dean J. H. Hilton, who has resigned to become President of Iowa State College effective July 1. In his new position Dr. Colvard will be in charge of administration of the College of Agriculture, the Agricultural Experiment Station, and the Agricultural Extension Service.

C. E. Lindley has been appointed Head of the Department of Animal Husbandry at the Mississippi State College and Agricultural Experiment Station, State College, Mississippi.

Charles M. Thompson, who has been working on his doctorate at Oklahoma A & M College, has been appointed Assistant in Animal Nutrition and Assistant Professor at the University of Kentucky and State Agricultural Experiment Station.

George M. Sidwell received his doctorate in Genetics and Animal Breeding at Iowa State College in March and has returned to duty at the Southwestern Range and Sheep Breeding Laboratory at Fort Wingate, New Mexico. He is employed as Animal Husbandman in Sheep Breeding Investigations by the Bureau of Animal Industry, United States Department of Agriculture.

H. S. Willard, member of the Animal Production Department since 1922, will spend a year in Palestine with headquarters at Tel-Aviv, Israel. His assignment to begin June 1 will involve coordinating all the livestock work in that country with major emphasis on dairying. He has been granted leave from the University of Wyoming for the period.

R. H. Black, Associate Professor of Animal Husbandry at West Virginia State University and Agricultural Experiment Station, is acting Assistant Dean and Director at that institution during the absence of Director Varney who is serving as Chief of Staff for the Senate Committee on Agriculture and Forestry in Washington.

G. C. Graf has been made Head of the Dairy Department of the Virginia Agricultural Experiment Station. He succeeds Professor A. W. Holdaway who retired in October 1952. Dr. Graf has been a member of the V. P. I. dairy staff since 1945.

G. C. Herring, formerly Extension Animal Husbandman, has been made Assistant Director of Extension at the Virginia Polytechnic Institute.

John A. Alford is now Associate Bacteriologist in the Department of Veterinary Science at the Mississippi Agricultural Experiment Station.

Bernard B. Riedel has been appointed Associate Parisitologist in the Department of Veterinary Science at the Mississippi Agricultural Experiment Station.

Joseph E. Bertrant has been made Research Associate in the Animal Husbandry Department at the Lousiana State Agricultural Experiment Station.

R. M. Richard has been appointed Assistant Animal Nutritionist in the Department of Animal Husbandry at the North Dakota Agricultural Experiment Station.

R. L. Arthaud, formerly Assistant Instructor in Animal Husbandry at the University of Missouri, has been appointed Assistant Professor of Animal Husbandry at the Virginia Polytechnic Institute and Agricultural Experiment Station.

James E. Prier, former Head of the Department of Veterinary Science and Bacteriologist at the University of Wyoming, has resigned to accept a post in the New York State Medical College at Syracuse. He will be succeeded by Gordon W. Robertstad.

M. P. Plumlee has been appointed Junior Assistant Animal Husbandryman at the Indiana Experiment Station, not at the Nebraska Station as erroneously reported in February, 1953 issue of the JOURNAL OF ANIMAL SCIENCE.

Raymond F. Sewell, who recently completed the requirements for the Ph.D. degree at Cornell University, has accepted a position as Assistant Professor of Animal Husbandry at the University of Georgia.

INFORMATION FOR CONTRIBUTORS

1. Papers may be submitted reporting work whose ultimate objective is clearly the solution of a livestock production problem and whose contents should be of interest particularly to those dealing with livestock production problems. Review papers on subjects of general interest will also be published at intervals, and will be prepared on invitation by the Editorial Board.

2. All papers will be subject to critical review by the Editorial Board, or others designated by the Editor. Papers needing revision will be returned to authors and should be revised and returned promptly. Papers not suitable for publication will be returned to authors with a statement of reasons for not accepting them.

3. Papers submitted should be based on new and adequate information. The following are guides to style and form:

   (a) Manuscripts must be typed, double-spaced, and the ribbon copy submitted.

   (b) Pages must be numbered. The lines of text must be numbered in the left margin, beginning with one at the top of each page. This does not apply to tabular material.

   (c) Tables should be as few and as simple as is feasible for presentation of the essential data.

   (d) Legend for each figure should be typed on a separate sheet. Photographs should be carefully prepared and labeled. Magnifications of photomicrographs should be indicated on legends. Charts should be prepared in India ink. Typed material on charts is not acceptable. Material that will not reproduce satisfactorily will be returned for revision. For suggestions on preparing illustrative material see the "Style Brief" published by the Wistar Institute Press, Philadelphia. If in doubt, consult the Editor before putting material in finished form.

   (e) The introduction should consist only of a paragraph indicating very briefly the nature of the question asked and the reason for asking it. Reference to relevant literature should be made later in the discussion of the results. Concise presentation of data is desired and there should be evidence of statistical examination wherever obviously useful in the interpretation. Unsupported hypotheses should be avoided. The organization of a manuscript may vary with the nature of the material, but all manuscripts should contain a clear statement of application of the results or their relation to some problem of the livestock industry. Each paper should end with a brief summary in the form of an abstract containing the most pertinent data in the briefest possible form.

   (f) Literature citations must be listed in alphabetical order and should be referred to in the text by author and date, i.e., Castle (1924), or (Castle, 1924). Citations may be referred to by number in review articles where the number of citations is too great to permit convenient use of the above form. "Literature cited" lists should be typed in a style used in a current issue of the JOURNAL.

4. Manuscripts will be edited in the order received, and accepted papers will be published as nearly in this order as feasible.

5. There will be a charge for making engravings in excess of one page per paper and of printing tables in excess of two pages per paper. The author will be asked when his manuscript is accepted to indicate the institution, agency or individual that will assume responsibility for the charges and for the reprints ordered at that time.

6. Authors will receive galley proof of articles together with a form for supplying an abstract for "Biological Abstracts". *Corrected proof and abstract should be mailed to the Editor within three days after they are received. Failure to do this may result in delay of publication until the next issue.*

7. One author of each manuscript should be a member of the Society. Papers by non-members can be published only after approval by the Executive Committee.

8. A "News and Notes" section will be published in each issue, including Society announcements, changes in positions and other items of professional interest concerning the members, and other items of interest to the membership. All such items should be sent promptly to the Editor.

9. Abstracts of papers to be presented at the annual meetings of the Society will be published in the November issue. Such abstracts must not exceed 250 words in length, should be typed (double spaced) and the ribbon copy submitted, the lines on the page should be numbered, in the left margin, from top to bottom, and must be in the hands of the Secretary of the Society by August 15, preceding the meeting. These abstracts must be summaries of results and conclusions.

10. Presentation of a paper at the annual meeting does not exclude it from publication in complete form in the JOURNAL. Such papers may be submitted to the Editor and will be given equal consideration with others submitted.

11. All manuscripts and correspondence concerning them should be addressed to the Editor: Dr. L. E. Casida, Department of Genetics, University of Wisconsin, Madison, Wisconsin, or to the publishers: Boyd Printing Company, 372–374 Broadway, Albany 7, New York.

12. All correspondence concerning subscriptions to the JOURNAL OF ANIMAL SCIENCE and other business matters should be addressed to the Business Manager, Dr. J. I. Miller, Department of Animal Husbandry, Cornell University, Ithaca, N. Y., or to the publishers, Boyd Printing Company, 372–374 Broadway, Albany 7, New York.